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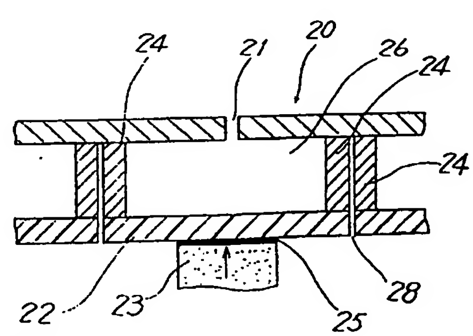
(54) Ink jet head.

(57) Disclosed is an ink jet head for jetting out an ink in a pressure chamber 26 by applying a pressure to the pressure chamber 26 for accommodating the ink. The ink jet head comprises a nozzle plate 20, including a nozzle 21 for jetting out the ink, a pressurizing plate 22 provided in parallel to the nozzle plate 20 and a wall member 24, exhibiting an elasticity, for forming the pressure chamber 26 by connecting the nozzle plate 20 to the pressurizing plate 22. The ink jet head further comprises a piezoelectric actuator 23, fixed to the pressurizing plate 22, for driving the pressurizing plate so as to deform the wall member 24.

FIG. 2



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The present invention relates to an ink jet head for jetting out ink by applying pressure to a pressure chamber which accommodates the ink.

There is frequently used an image forming apparatus such as a copying machine, a printer and a facsimile. In such an apparatus, an ink jet printer is utilized for the reason of having a simple construction. This ink jet printer forms an image on a recording medium by jetting out the ink out of an ink jet head.

In a prior proposal an ink jet head exists which jets out the ink by applying pressure to the ink within a pressure chamber. In this type of ink jet heads, a high conversion efficiency into an ink jet with respect to the applied pressure is desirable.

FIGS. 43A and 43B are views of assistance in explaining a first such proposal. FIGS. 44A and 44B are views of assistance in explaining a second such proposal.

As illustrated in FIG. 43A, an interior of a pressure chamber 2 is filled with the ink. A nozzle plate 1 has a nozzle 6 for jetting out the ink. A vibration plate 3 is provided in parallel to the nozzle plate 1. A piezo element (piezoelectric actuator) 4 for driving the vibration plate 3 is stuck to one side of this vibration plate 3. Upper and lower surfaces of this piezo element 4 are provided with a pair of electrodes 5 for applying a voltage to the piezo element 4.

A wall member 8 for forming the pressure chamber 2 is provided between this nozzle plate 1 and the vibration plate 3. The wall member 8 is formed of a rigid material. Then, a part of the wall member 8 is formed with a supply port 7 for supplying the ink to the pressure chamber 2.

The operation based on this construction will be explained. As illustrated in FIG. 43B, the voltage is applied to the electrodes 5 so as to contract the piezo element 4. The piezo element 4 is thereby contracted. However, the side, connected to the vibration plate 3, of the piezo element 4 can not be contracted. For this reason, there is produced a difference in a contraction quantity between the upper surface and the lower surface of the piezo element 4.

Consequently, the piezo element 4 and the vibration plate 3 are bent toward the pressure chamber 2. With this bending, the pressure is applied on the pressure chamber 2. Therefore, the ink within the pressure chamber 2 is pushed out and spurts in the form of ink particles 9 out of the nozzle 6. This method is known as a so-called d_{31} mode in which the piezo element 4 is stretched and contracted in parallel to the vibration plate 3. Similarly, there is a so-called d_{33} mode in which the piezo element 4 is stretched and contacted perpendicularly to the vibration plate 3.

FIG. 44A is a view showing another device according to the prior art (Specification of Japanese Patent Application No.3-511685, filed on July 9, 1991, International Patent Application No. PCT JP 91/00916, International Patent Laid-Open No. WO 92/00849).

As shown in FIG. 44A, the wall member provided between the nozzle plate 1 having the nozzle 6 and the vibration plate 3 is constructed by laminating a rigid member 8 and an elastic member 11. Then, a wire dot head 12 serving as a driving element is disposed in a face-to-face relationship with the vibration plate 3.

The operation thereof will be explained. As depicted in FIG. 44B, the vibration plate 3 is pushed with wire driving by the wire dot head 12. The vibration plate 3 thereby contacts the elastic member 11, thus applying the pressure on the pressure chamber 2. As a result, the ink is made to spurt out of the pressure chamber 2.

According to the first proposal shown in FIG. 43A, however, the peripheral portion of the vibration plate 3 is fixed to the wall of the pressure chamber 2. For this reason, when the vibration plate 3 is bent, there is generated a large stress at a connecting portion of the vibration plate 3 to the wall of the pressure chamber 2. The vibration plate 3 vibrates at several kHz, and, hence, fatigue breaking is caused by this stress, resulting in such a possibility that the connecting portion is to be ruptured.

Further, according to the first proposal illustrated in FIG. 43A, a force generated by the piezo element is a sum of a force of for pushing out the ink and a force for bending the vibration plate 3. The peripheral portion of the vibration plate 3 is, however, fixed to the wall of the pressure chamber 2, and hence there is required a large force for bending the vibration plate 3. As a result, the force for pushing out the ink is reduced. For this reason, there is worsened the conversion efficiency into the ink pushing force with respect to the generated force of the piezo element.

Furthermore, according to the first proposal illustrated in FIG. 43A, if the generated force of the piezo element is fixed, it is required that the center of the vibration plate 3 be pushed by the piezo element in order to maximize the bend of the vibration plate 3. That is, if the central portion of the vibration plate 3 is not pushed, the bend of the vibration plate 3 assumes an asymmetry with respect to the center, with the result that the ink pushing force is decreased. As a size of the vibration plate 3 is on the order of 1 mm x 1 mm, it is required that a head assembling accuracy be restrained down to several-tens μm or smaller enough to push the central portion thereof. The assembly is therefore difficult.

Next, according to the second proposal illustrated in FIG. 44A, as shown in FIG. 44B, even when the wire dot head 12 is stopped, residual vibrations are left in the vibration plate 3. If an amplitude of the residual vibration is larger than a certain threshold, the ink particles are again formed. Satellite particles 10 are thereby generated upon jetting out of the nozzle. The head jets out the ink particles while moving.

Therefore, when the satellite particles exist, there are printed the dots, the number of which corresponds to the number of the satellite particles in the moving direction of the head. Consequently, a character width is expanded, resulting in a deteriorated printing quality such as a blur of the character or the like.

Further, according to the second proposal shown in FIG. 44A, for the purpose of separating the ink head from the driving portion, the vibration plate 3 is separated from a pressurizing mechanism of the wire dot head 12, and there is formed a gap therebetween. For this reason, there can not be taken a high-efficiency driving method, viz., a so-called negative polarity driving method by which the vibration plate 3 is driven in a direction opposite to the nozzle-direction; the ink is sucked into the pressure chamber 2; and, thereafter, the vibration plate 3 is driven in the nozzle-direction to jet out the ink.

An embodiment of the present invention may provide an ink jet head for enhancing a conversion efficiency into an ink pushing force from a generated force of a piezo element.

An embodiment of the present invention may also provide an ink jet head for increasing a durability of a head.

A further embodiment of the present invention may provide an ink jet head which facilitates the assembly thereof.

An embodiment of the present invention may also provide an ink jet head for preventing an occurrence of satellite particles.

A yet further embodiment of the present invention may provide an ink jet head for making a negative polarity drive effective.

According to the present invention, there is provided an ink jet head for jetting out ink in a pressure chamber by applying pressure to said pressure chamber, which is adapted for accommodating the ink, said ink jet head comprising a nozzle plate including a nozzle for jetting out the ink; a pressurizing plate provided in parallel to said nozzle plate; a wall member, exhibiting elasticity, for forming said pressure chamber by connecting said nozzle plate to said pressurizing plate; and a piezoelectric actuator, fixed to said pressurizing plate, for driving said pressurizing plate so as to deform said wall member.

According to a development of the present invention, the wall member of the pressure chamber is formed of an elastic material. Then, this wall member is deformed through the pressurizing plate by the piezoelectric actuator fixed to the pressurizing plate. A volume of the pressure chamber is thereby varied, thus pushing out the ink.

That is, the pressurizing plate that is hard to bend is employed in place of the vibration plate. Then, the pressurizing plate is driven by the piezoelectric actuator to deform the wall member. The volume of the pressure chamber is thus changed. With this arrangement, because of using no vibration plate, the fatigue breaking due to the vibrations can be prevented. With this prevention, the occurrence of the satellite particles can be also prevented.

Moreover, the pressurizing plate is extruded without bending the vibration plate, and, therefore, an ink jetting energy can be increased. Besides, the piezoelectric actuator is fixed to the pressurizing plate, whereby the negative polarity drive can be carried out. This makes it possible to jet out the ink at a high efficiency.

Other features and advantages of the present invention will become readily apparent from the following description given purely by way of example, when taken in conjunction with the accompanying drawings.

The accompanying drawings, illustrate presently preferred embodiments of the invention, and together with the general description given above and the detailed description of the preferred embodiments given below, serve to explain the principle of the invention, in which:

FIGS. 1A and 1B are views showing a device in accordance with an embodiment of the present invention;

FIG. 2 is a sectional view showing an embodiment o the present invention;

FIG. 3 is a sectional view illustrating a first modified example of the embodiment;

FIG. 4A is a view showing a positive polarity drive waveform FIGS. 4B, 4C, 4D and 4E are views of assistance in explaining the positive polarity driving operation;

FIG. 5A is a view illustrating a negative polarity drive waveform FIGS. 5B, 5C, 5D, 5E and 5F are views of assistance in explaining the negative polarity driving operation;

FIG. 6 is a sectional view illustrating a second modified example;

FIG. 7 is a sectional view illustrating a third modified example;

FIG. 8 is a sectional view illustrating a fourth modified example;

FIGS. 9A and 9B are views showing a configuration of a fifth modified example;

FIGS. 10A and 10B are views showing a configuration of a sixth modified example;

FIGS. 11A and 11B are views illustrating a configuration of a seventh modified example;

FIG. 12 is a view illustrating a configuration of an eighth modified example:

FIGS. 13A and 13B are views illustrating a configuration of a ninth modified example;

FIGS. 14A, 14B and 14C are views of assistance in explaining the operation in the ninth modified example;

FIGS. 15A and 15B are sectional views showing a tenth modified example;

FIGS. 16A and 16B are sectional views showing an eleventh modified example;
FIG. 17 is a fragmentary view illustrating a multi-nozzle head;
FIG. 18 is a sectional view of the multi-nozzle head of FIG. 17;
FIG. 19 is a sectional fragmentary view of the multi-nozzle head of FIG. 18;
FIG. 20 is a view of assistance in explaining a screen printing method of forming an elastic layer;
FIG. 21 is a view of assistance in explaining an offset printing method of forming the elastic layer;
FIG. 22 is a view of assistance in explaining another method of uniformizing a thickness;
FIG. 23 is a view of assistance in explaining a pressure distribution in a pressure chamber;
FIG. 24 is a view of assistance in explaining a passageway plate;
FIG. 25 is a view of assistance in explaining another passageway plate;
FIGS. 26A and. 26B are views of assistance in explaining a pressurizing plate;
FIGS. 27A and 27B are view of assistance in explaining the pressurizing plate having the construction shown in FIGS. 26A and 26B;
FIG. 28 is a view of assistance in explaining another pressurizing plate;
FIGS. 29A and 29B are views of assistance in explaining still another pressurizing plate;
FIG. 30 is a view showing a configuration of another pressure damper;
FIG. 31 is a view showing a configuration of still another pressure damper;
FIG. 32 is a view showing a configuration of a further pressure damper;
FIG. 33 is a perspective view illustrating a piezoelectric actuator;
FIG. 34 is a plan view of a lead frame used for the piezoelectric actuator of FIG. 33;
FIG. 35 is a perspective view of the lead frame of FIG. 34;
FIG. 36 is a view showing a configuration when assembling the piezoelectric actuator of FIG. 33;
FIG. 37 is a view of assistance in explaining a structure of an electrode of FIG. 36;
FIG. 38 is a cross view of a multi-nozzle head;
FIG. 39 is a side view of the multi-nozzle head;
FIG. 40 is an explanatory view of another lead frame;
FIG. 41 is an explanatory view showing a connecting state of the lead frame of FIG. 40;
FIG. 42 is an explanatory view showing an electrode structure of FIG. 41;
FIGS. 43A and 43B are views of assistance in explaining a first prior proposal; and
FIGS. 44A and 44B are views of assistance in explaining a second prior proposal.

FIGS. 1A and 1B are views illustrating an embodiment of the present invention.

As illustrated in FIG. 1A, a wall member 24 is provided between a nozzle plate 21 having a nozzle and a pressurizing plate 22. This wall member 23 exhibits an elasticity. Then, a piezoelectric actuator 23 is fixed to the pressurizing plate 22.

As shown in FIG. 1B, the piezoelectric actuator 23 drives the pressurizing plate 22 to stretch and contract the wall member 24. An ink is thereby jetted via the nozzle 21 from within a pressure chamber 26.

Thus, a vibration plate is not bent, and, hence, fatigue breaking due to the vibration can be prevented. With this prevention, satellite particles can be also prevented from being produced.

Further, the pressurizing plate is extruded without bending the vibration plate, and, therefore, an ink jetting energy can be increased. Besides, since the piezoelectric actuator is fixed to the pressurizing plate, a negative polarity drive can be performed. This makes it possible to jet out the ink at a high efficiency.

FIG. 2 is a sectional view showing one embodiment of the ink jet head.

As shown in FIG. 2, the pressurizing plate 22 is provided in parallel to the nozzle plate 20 including the nozzle 21 for jetting out the ink. The pressurizing plate 22 is composed of a thin metal sheet or the like. This pressurizing plate 22 has a thickness enough not to be bent when the piezoelectric actuator presses the pressurizing plate 22. The pressurizing plate 22 involves the use of a metal such as nickel having, e.g., a thickness on the order of 20 μm and a Young's modulus of 2.2×10^{11} Pa (Pa is pascal, Pa = N/m^2).

An elastic member constituting the wall member 24 is provided between the nozzle plate 20 ad the pressurizing plate 22. This wall member 24 is provide along the periphery of the pressure chamber 26, thus forming the pressure chamber 26. This elastic member 24 is composed of, preferably, a rubber or a resin having a Young's modulus of the order of 9.6×10^5 Pa - 1×10^9 Pa. In this example, there is employed a silicon rubber having a Young's modulus of 9.6×10^5 Pa. Further, a height of his elastic member 24 is approximately 60 μm.

A piezo element (piezoelectric actuator) 23 is fixed to this pressurizing plate 22 with a bonding agent. Electrodes 25 are attached to upper and lower portions of this piezo element 23. The piezo element 23 is of a type in a d_{33} mode. Accordingly, the piezo element 23 is stretched and contracted in up-and-down directions in the Figure by applying a voltage to the electrodes 25.

Further, the wall member 24 is formed with a slit 28 between the adjacent pressure chamber and the wall member 24. With this arrangement, an interference between the pressure chambers is prevented.

In accordance with this embodiment, when apply-

ing the voltage to the piezo element 23, the pressurizing plate 22 pushes and contracts the wall member 24 by a generated force of the piezo element 23. As a result, the pressurizing plate 22 moves in parallel and extrudes the ink from within the pressure chamber 26.

Note that this embodiment gives an example of driving in the d_{33} mode. The same effect is, however, obtained in a d_{31} mode wherein the electrodes are fitted to right and left side surfaces of the piezo element 23, and the piezo element 23 is stretched and contracted in the up-and-down direction in the Figure.

Also, the piezoelectric actuator is structured such that a plurality of units each including a piezo body sandwiched in between a pair of electrodes are laminated, thereby making it possible to increase a displacement and the generated force.

With this construction, the fatigue breaking can be prevented because of involving the bending of the vibration plate. This leads to saving of the energy needed for the bending thereof, and, therefore, the energy generated by the piezo element 23 can be directly applied to the ink jetting energy. Besides, the vibration plate is not bent, and it is therefore permitted that a positioning accuracy of the parts may not be high. Further, the piezo element 23 is closely fitted to the pressurizing plate 22. Consequently, there is no residual vibration, and the satellite particles can be prevented from being produced.

FIG. 3 is a sectional view showing a first modified example of the ink jet head.
FIGS. 4A through 4E are views of assistance in explaining a positive polarity drive operation thereof.
FIGS. 5A to 5F are views of assistance in explaining a negative polarity drive operation.

Referring to FIG. 3, the explanation will be given while putting the like numerals on the same elements as those explained in FIG. 2. In the embodiment of FIG. 2, the whole wall member 24 is composed of the elastic material. In a modified example thereof, the wall member 24 is structured in such a way that a wall 24-1 having a high rigidity and an elastic member 24-2 are laminated.

The high-rigidity wall 24-1 is formed on the side of the nozzle plate 20. Then, the high-rigidity wall 24-1 is made of, preferably, a metal or a resin having its Young modulus on the order of 1×10^{10} Pa or more. In addition, the high-rigidity wall 24-1 is 50 μm in height. The elastic member 24-2 is formed on the side of the pressurizing plate 22. Then, the elastic member 24-2 is 10 μm high. The elastic member 24-2 involves the use of a silicon rubber having its Young modulus of 9.6×10^5 Pa in this example.

The laminated structure of the high-rigidity wall 24-1 and the elastic member 24-2 is formed in the following manner. A liquid one- or two-pack silicone rubber is formed on the high-rigidity wall 24-1 by a printing method such as screen printing, etc., and, after positioning the pressurizing plate 22, the silicone rubber is hardened at a normal or high temperature (approximately 120°C), thus forming a plate member.

In this example, the above high-rigidity wall 24-1 is formed with an ink supply port 27 for supplying the ink into the pressure chamber 26. Further, the piezo element 23 is fixed to the pressurizing plate 22 with a bonding agent 30. The electrodes 25 are attached to the upper and lower portions of this piezo element 23. The piezo element 23 is of the type in the d_{33} mode. Accordingly, the piezo element 23 is stretched and contracted in the up-and-down directions in the Figure by applying the voltage to the electrodes 25.

In this example, only a portion, having a height necessary for a deformation, of the wall member is composed as an elastic member 24-2. With this arrangement, the wall member 24 is prevented from being bent. It is therefore possible to further enhance an efficiency of transforming the energy of the piezo element 23 into the ink jetting energy.

A positive polarity driving method will be explained with reference to FIGS. 4A through 4E. According to this driving method, a positive polarity pulse as shown in FIG. 4A is applied to the piezo element 23 to push the pressurizing plate 22 in one direction toward the nozzle, thereby jetting out the ink.

FIG. 4B shows an initial state where the voltage is not applied. When a timing $t = t_2$, and when the voltage is applied to the piezo element 23, the pressurizing plate 22 pushes and contracts the elastic member 24-2 by the generated force of the piezo element 23. As illustrated in FIG. 4C, in consequence of this, an ink surface portion known as a meniscus bulges out of the nozzle 21 due to a displacement of the pressurizing plate 22, and, therefore, an intra-ink pressure is abruptly decreased due to the air along the periphery of the bulged-out ink.

When further increasing the applied voltage, the pressurizing plate 22 further shifts in parallel, whereby the pressure within the pressure chamber 26 rises. As illustrated in FIG. 4D, at this time, the quantity of the ink from the nozzle 21 increases.

As shown in FIG. 4E, when the piezo element 23 stops, the displacement of the pressurizing plate 22 is also abruptly stopped. A flow of the ink within the pressure chamber is also stopped, but the ink emerging from the nozzle moves forward by its inertia, with the result that the ink is eventually separated into ink particles.

Next, a negative polarity driving method will be explained with reference to FIGS. 5A to 5F. As illustrated in FIG. 5A, according to this driving method, the piezo element 23 is driven by a triangular wave in a negative direction. The pressurizing plate 22 is thereby driven once in a direction opposite to the nozzle-direction, and, after sucking the ink into the pressure chamber, the pressurizing plate 22 is returned in the nozzle-direction, thus jetting out the ink.

FIG. 5B shows the initial state where the voltage is not applied. As illustrated in FIG. 5C, when applying the voltage to the piezo element 23, the pressurizing plate 22 is displaced by the generated force of the piezo element 23 in the direction opposite to the nozzle. The meniscus is pulled into the nozzle 21 with the displacement of the pressurizing plate 22.

When the applied voltage to the piezo element 23 is set to zero, the piezo element 23 returns to the original position. At this time, the pressurizing plate 22 also goes back to the original position. As depicted in FIG. 5D, the meniscus also starts shifting. Then, the meniscus is confined into the pipe-like nozzle 21, and, hence, the rise in the pressure of the pressure chamber 26 due to the displacement of the pressurizing plate 22 is transferred the head of the meniscus. The above-described pressure always acts on the ink and the meniscus shifting within the nozzle 21, and consequently the ink is accelerated till the ink reaches the outlet of the nozzle 21.

Next, as illustrated in FIG. 5E, the ink jets out of the nozzle 21 with a kinetic quantity obtained within the nozzle 21. As a total sum of the kinetic quantity of the ink at the instant of jetting out of the nozzle 21 augments, a velocity of the ink column becomes higher than by the positive polarity drive.

As shown in FIG. 5F, when the piezo element 23 stops, the displacement of the pressurizing plate 22 is also abruptly stopped. The flow of the ink within the pressure chamber is also stopped. However, the ink emerging from the nozzle moves forward by its inertia, with the result that the ink is eventually separated into ink particles.

This positive polarity drive is compared with the negative polarity drive. The velocity of the ink particles has such a relationship that $v_2 > v_1$, where the v_1 is the velocity with the positive polarity, and v_2 is the velocity with the negative polarity.

Next, let VIA be the volume ranging from the meniscus within the nozzle to the outlet of the nozzle when the piezo element 23 starts pushing the ink. Then, let VIP be the value when converting a displacement volume of the piezo element 23 into a volume of the nozzle portion.

In the case of the positive polarity drive, the volume V1 of the ink particles is V1 = VIP. That is, the meniscus is not pulled in from the nozzle outlet, and therefore VIA = 0. On the other hand, in the case of the negative polarity drive, V1 = VIP - VIA. Accordingly, the volume of the ink particles in the negative polarity drive is smaller than in the positive polarity drive.

A kinetic energy E inherent in the ink particles is expressed such as $E = 0.5 \cdot m \cdot v^2$. The negative polarity drive has a mass m slightly smaller than that of the positive polarity drive but has the velocity v considerably higher than that of the positive polarity drive. Hence, the total kinetic energy E is slightly larger than that of the positive polarity drive. Namely, it follows that the negative polarity drive exhibits a higher conversion efficiency from the input energy to the piezoelectric actuator 23 into the kinetic energy of the ink particles than the positive polarity energy.

Further, in the case of the negative polarity drive, the ink is accelerated within the nozzle 21, and, therefore, a spurting direction of the ink particles is more stable than by the positive polarity drive. Accordingly, in the ink jet, the negative polarity drive is more desirable than the positive polarity drive.

In this respect, according to the present invention, the negative polarity drive is practicable. As a matter of course, this does not intend to hinder the application to the positive polarity drive. Note that this embodiment also gives a drive example in the d_{33} mode, but the same effect is obtained in a d_{31} mode, too.

FIG. 6 is a sectional view illustrating a second modified example of the ink jet head.

Referring to FIG. 6, the same elements as those explained in FIG. 3 are marked with the like numerals. In this modified example, the pressurizing plate 22 is provided for every pressure chamber 26. This arrangement prevents an interference of the pressurizing plates 22 with each other. As a matter of course, the piezo element 23 is provided corresponding to each pressurizing plate 22.

FIG. 7 is a sectional view illustrating a third modified example of the ink jet head.

Referring to FIG. 7, the same elements as those described in FIG. 3 are marked with the like numerals. In this modified example, the pressurizing plate 22 is provided for every pressure chamber 26. This arrangement prevents an interference of the pressurizing plates 22 with each other. Also, the piezo element 23 is provided corresponding to each pressurizing plate 22. Further, the elastic member 24-2 is formed with a slit 29. The elastic member 24-2 is partitioned by this slit into two pieces of elastic members.

A separation from the pressure chamber adjacent to the elastic member can be attained, thereby making it possible to prevent the mutual interference between the elastic members. Besides, the high-rigidity wall 24-2 can be shared with the adjacent pressure chamber.

In accordance with these embodiment, the elastic member 24-2 can be also formed by use of the bonding material exhibiting the elasticity.

FIG. 8 is a sectional view illustrating a fourth modified example of the ink jet head

Referring to FIG. 8, the same elements as those shown in FIG. 3 are marked with the like numerals.

As shown in FIG. 8, the wall member 24 is constructed of the high rigidity wall 24-1 and a bellows 31. The bellows 31 is formed of a metal. In this embodiment, the elastic member 24-2 of FIG. 3 is replaced with the bellows 31. In accordance with this

embodiment also, the same action and effect as those shown in FIG. 3 are exhibited.

FIGS. 9A and 9B are views each showing a configuration of a fifth modified example of the ink jet head. FIG. 9A ia a sectional view thereof, and FIG. 9B is a top view thereof.

In FIGS. 9A and 9B, the same elements as those shown in FIG. 2 are marked with the like numerals. In this modified example, a pair of piezo elements 23 are disposed outwardly of the side surface of the elastic member 24 constituting the wall member. One ends of the piezo elements 23 are connected to the pressurizing plate 22, while the other ends thereof are connected to the nozzle plate 20.

The operation based on this configuration will be explained. The pressurizing plate 22 is pulled in toward the nozzle plate 20 by contacting the piezo elements 23, thereby increasing the pressure within the pressure chamber 26. The ink is thereby jetted out. This configuration exhibits the same effect as that shown in FIG. 2. Further, the thickness of the head can be reduced.

FIGS. 10A and 10B are views each illustrating a configuration of a sixth modified example of the ink jet head. FIG. 10A is a sectional view thereof, and FIG. 10B is a top view thereof.

Referring to FIGS. 10A and 10B, the same elements as those shown in FIG. 2 are marked with the like numerals. In this modified example, the piezo element 23 is disposed inwardly of the two elastic members 24 constituting the wall member. One end of the piezo element 23 is connected to the pressurizing plate 22, while the other end thereof is connected to the nozzle plate 20.

The operation based on this configuration will be described. The pressurizing plate 22 is pulled in toward the nozzle plate 20 by contacting the piezo element 23, thereby increasing the pressure within the pressure chamber 26. The ink is thereby jetted out. This configuration exhibits the same effect as that shown in FIG. 2. In addition to this, the thickness of the head can be reduced.

FIGS. 11A and 11B are views each illustrating a configuration of a seventh modified example of the ink jet head. FIG. 11A is a sectional view thereof, and FIG. 11B is a top view thereof.

Referring to FIGS. 11A and 11B, the same elements as those shown in FIG. 2 are marked with the like numerals. In this modified example, the pair of piezo elements 23 are attached to the side surfaces of the elastic members 24 constituting the wall member. The piezo elements 23 are employed in a d_{15} mode (lateral shear mode). One side surfaces of the piezo elements 23 are connected to the pressurizing plate 22, while the other side surfaces thereof are connected via fitting members 32 to the nozzle plate 20.

When applying the voltage to the piezo elements 23, a lateral shear is caused in arrowed directions in the Figure, thereby displacing the pressurizing plate 22 toward the nozzle plate 20. With this operation, the pressure in the pressure chamber 26 is increased enough to jet out the ink. According to this configuration, the same effect as that shown in FIG. 2 is exhibited, and, at the same time, the thickness of the head can be reduced.

FIGS. 12A and 12B are views each illustrating a configuration of an eighth modified example of the ink jet head. FIG. 12A is a sectional view thereof, and FIG. 12B is a top view thereof.

Referring to FIGS. 12A and 12B, the same elements as those shown in FIG. 2 are marked with the like numerals. In this modified example, the piezo elements 23 are employed in the d_{15} mode (lateral shear mode). Two pieces of piezo elements 23 are stuck to each other are fixed to an unillustrated head support member via fitting members 33 provided on the right and left side surfaces.

When applying the voltage to the piezo elements 23, the lateral shear is caused in arrowed directions in the Figure. The stuck portions of the piezo elements 23 are thereby displaced upward, which in turn displaces the pressurizing plate 22 toward the nozzle plate 20. With this operation, the pressure in the pressure chamber 26 is increased enough to jet out the ink. According to this configuration also, the same effect as that shown in FIG. 2 is exhibited.

FIGS. 13A and 13B are views each illustrating a configuration of a ninth modified example of the ink jet head. FIG. 13A is a sectional view thereof, and FIG. 13B is a perspective view thereof. FIGS. 14A, 14B and 14C are views of assistance in explaining the operation thereof.

Referring to FIGS. 13A and 13B, the same elements as those shown in FIG. 2 are marked with the like numerals. According to this modified example, in the configuration of FIG. 2, an ink supply port 27 is formed in the wall member 24 composed of the elastic member.

The operation thereof will be discussed with reference to FIGS. 14A, 14B and 14C. In general, when the pressurizing plate 22 is displaced and starts pushing the ink, some ink flows back via the supply port 27 toward an unillustrated ink supply tank. A counterflow quantity is equivalent to a loss of the energy and is therefore desirably as small as possible.

As illustrated in FIGS. 14B and 14C, in the negative polarity drive, when the ink is pushed out by the pressurizing plate 22, the wall member 24 is contracted, and, hence, a sectional area of the supply port 27 of the wall member 24 is also narrowed. When the sectional area is narrowed, a passageway resistance increases, with the result that the ink is hard to flow back.

On the other hand, when the ink is sucked into the pressure chamber 26, the wall member 24 is stretch-

ed. Accordingly, the sectional area of the supply port 27 is expanded, whereas the passageway resistance is reduced. The ink thereby flows into the pressure chamber 26 in a short time.

As described above, the supply port 27 is formed in the wall member 24, and a valve function can be thereby incorporated into the supply port 27 itself. For this reason, the loss energy can be reduced, and the ink jetting energy can be increased. Note that a dimension of the section, when narrowed, of the supply port 27 may be set several times or under as large as the displacement quantity (approximately 1 μm) of the pressurizing plate 22. Further, in the positive polarity drive also, the same operation is to be performed.

FIGS. 15A and 15B are views each illustrating a configuration of a tenth modified example of the ink jet head. FIG. 15A is a sectional view thereof, and FIG. 15B is a perspective view thereof.

Referring to FIGS. 15A and 15B, the same elements as those shown in FIG. 3 are marked with the like numerals. According to this modified example, in the configuration of FIG. 3, the ink supply port 27 is formed in the elastic member 24-2.

In this modified example also, when the ink is pushed out by the pressurizing plate 22, the elastic member 24-2 is contracted. With this contraction, the sectional area of the supply port 27 of the wall 24-2 is also narrowed. When the sectional area is narrowed, the passageway resistance increases, with the result that the ink is hard to flow back.

On the other hand, when the ink is sucked into the pressure chamber 26, the elastic member 24-2 is stretched, and consequently the sectional area of the supply port 27 is expanded. The passageway resistance is thereby reduced and, therefore the ink flows into the pressure chamber 26 in a short time.

As explained above, the supply port 27 is formed in the elastic member 24-2, and the valve function can be thereby incorporated into the supply port 27 itself. For this reason, the loss energy can be reduced, and the ink jetting energy can be increased.

FIGS. 16A and 16B are views each illustrating a configuration of an eleventh modified example of the ink jet head. FIG. 16A is a front sectional view thereof, and FIG. 16B is a cross-sectional view thereof.

Referring to FIGS. 16A and 16B, the same elements as those shown in FIG. 7 are marked with the like numerals. According to this modified example, in the configuration of FIG. 7, the ink supply port 27 is formed in the elastic member 24-2.

In this modified example also, when the ink is pushed out by the pressurizing plate 22, the elastic member 24-2 is contracted. For this reason, the sectional area of the supply port 27 of the elastic member 24-2 is also narrowed. When the sectional area is narrowed, the passageway resistance increases, with the result that the ink is hard to flow back.

On the other hand, when the ink is sucked into the pressure chamber 26, the elastic member 24-2 is stretched, and, accordingly, the sectional area of the supply port 27 is expanded. As a result of this, the passageway resistance is reduced, and the ink flows into the pressure chamber 26 in a short time.

As described above, the supply port 27 is formed in the elastic member 24-2, and the valve function can be thereby incorporated into the supply port 27 itself. For this reason, the loss energy can be reduced, and the ink jetting energy can be increased.

In the above modified example also, the elastic member 24-2 can be formed by use of the bonding agent exhibiting the elasticity.

In addition to the embodiment discussed above, in the modified examples shown in FIGS. 13A through 16A also, the positive and negative polarity drive methods explained in FIGS. 4 and 5 can be utilized. Further, in the modified examples shown in FIGS. 13A through 16A also, the configurations explained referring to FIGS. 8 through 12 are applicable.

Next, a multi-nozzle head will be described.

FIG. 17 is a fragmentary view of the multi-nozzle head. FIG. 18 is a sectional view thereof. FIG. 19 is a fragmentary sectional view thereof.

As illustrated in FIG. 17, the multi-nozzle head includes a nozzle plate 40, a passageway plate 41, an elastic plate 42, a pressurizing plate 43, a holder 44 and a piezoelectric actuator 45.

As depicted in FIGS. 18 and 19, the nozzle plate 40 has a multiplicity of nozzles 40-1. In the illustrative example, there are formed four rows of nozzles, each row consisting of 16 nozzles. Then passageway plate 41 constitutes the above high-rigidity member 24-1. Each pressure chamber 46 and a common ink chamber 48 are defined by this passageway plate 41. The elastic plate 42 serves as the above-stated elastic member 24-2. The pressurizing plate 43 forms each pressurizing plate 22. The holder 44 holds the piezoelectric actuator 45, and, at the same time, the nozzle plate 40, the passageway plate 41, the elastic plate 42 and the pressurizing plate 43 are fixed to this holder 44.

As illustrated in FIG. 18, this passageway plate 41 is formed with an ink supply port 47 through which the pressure chamber 46 communicates with the common ink chamber 48. Accordingly, this multi-nozzle head is constructed such that the head in each of the embodiments of FIGS. 3 to 6 is provided with multi-nozzles.

Next, a method of forming the respective plates constituting the multi-nozzle head will be explained. The explanation will start with touching on the elastic plate 42.

FIG. 20 is a view of assistance in explaining the screen printing method of manufacturing the elastic plate. FIG. 21 is a view of assistance in explaining the offset printing method of manufacturing the elastic

plate.

An important point in terms of forming the elastic plate is that the plate is formed with a uniform thickness. Also, in the mass production, it is required that the elastic plate be formed to have the uniform thickness. According to this invention, this elastic plate is manufactured by use of a liquid elastic member.

As illustrated in FIG. 20, the passageway plate 41 is bonded onto the nozzle plate 40. A mesh 81 for the screen printing is provided on the surface of this passageway plate 41 on the side of the pressurizing plate. Then, an elastic material 82 is traced by a blade (squeegee) 80 through the mesh 81. With this operation, the elastic material 82 is uniformly coated.

The elastic material 82 is coated on the periphery of the pressure chamber. Thereafter, the pressurizing plate 43 is positioned with and put on the coating surface, thus effecting pressurization. Further, the elastic material 82 is hardened at a normal or high temperature (approximately 120°C) and thus bonded thereto. The elastic plate 42 is thereby formed.

This elastic material 82 is preferably a rubber or a resin having its Young modulus on the order of 1×10^5 Pa - 1×10^9 Pa after being hardened. In this embodiment, a silicon rubber having a Young modulus of 9.6×10^5 is employed. A viscosity when coated is 200 cp. Further, the mesh is selected so that the thickness of the elastic layer is 10 μm.

Thus, the elastic layer 82 can be formed based on the screen printing.

FIG. 21 illustrates an example of forming the elastic layer by the offset printing.

As depicted in FIG. 21, a hopper 23 is filled with a liquid elastic material. A liquid layer of the elastic material having a uniform thickness is formed on a coating roller 84-4 through a group of rollers 84-1 to 84-3 exhibiting a high affinity (wettability) with this elastic material. Thereafter, the nozzle plate 40 mounted with the passageway plate 41 is moved in the arrowed direction. With this movement, the liquid elastic layer is formed on the passageway plate 41. Thereafter, the pressurizing plate 43 is positioned with and put on the coating surface, thus performing the pressurization. Further, the liquid elastic layer is hardened at the normal or high temperature (approximately 120°C) and then bonded thereto. In this manner, the elastic layer 82 is formed by the offset printing method.

Thus, the liquid elastic material is coated on the passageway plate 41, thereby making it feasible to form the elastic layer on the passageway plate 41. As a result, the elastic layer having the uniform thickness can be easily formed. Besides, the printing-based method is taken, and, hence this is suited to the mass production.

Additionally, a method of further uniformizing the thickness will be explained. According to the above-mentioned method, the elastic material is in the liquid state and hardened while being mounted with the pressurizing plate 43. If this elastic material remains liquid, however, the thickness of the elastic layer is hard to control. Under such a condition, the liquid elastic material is coated on the passageway plate 41 and is thereafter once hardened. With this hardening, the bonding material is coated on the elastic material after reaching a state where the elastic material does not flow out even by pushing the pressurizing plate 43. Then, the elastic material is hardened while pushing the pressurizing plate 43.

The pressurizing plate 43 and the passageway plate 41 are thereby bonded to each other. Then, after releasing the pressurizing plate 43 from being pushed, the elastic layer reverts to the thickness in the initially hardened state. Therefore, the elastic layer having the uniform thickness can be formed. The elastic material available for the elastic layer is also usable as this bonding material.

As explained above, the thickness of the elastic layer can be uniformized by providing a process of once hardening the elastic layer.

FIG. 22 is a view of assistance in explaining another method of uniformizing the thickness.

As shown in FIG. 22, particles 42-1 having the maximum particle size equal to a desired film thickness are mixed in the liquid elastic material 42. That is, there are prepared the particles 42-1 filtered beforehand so that the maximum particle size is equal to the desired film thickness. The particles 42-1 are mixed in the liquid elastic material 42 and then sufficiently dispersed. The particles 42-1 are employed as a spacer. This prevents the thickness of the elastic layer from being under than maximum particle size even when pressurized. As a result, the elastic layer which is thin but has the uniform thickness can be formed.

For instance, 30 % of SiO_2 particles having the maximum particle size on the order of 10 μm are mixed in the one-pack silicone rubber. The thus mixed body is screen-printed on the passageway plate 41. Then, after the pressurizing plate 43 made of a resinous film has been stuck, a heating process is effected at 120°C, thus performing the hardening process. Thus, the thickness of the elastic layer 42 can be set down to 10 μm. The particles 42-1 may involve the use of inorganic materials such as SiO_2, TiO or organic materials such as polystyrene, polycarbonate. Further, a proper particle content is 5 wt% - 60 wt%.

This method is suited to the negative polarity drive because of the thickness of the elastic layer 42 being not under 10 μm.

Next, the passageway plate will be described.

FIG. 23 is a view of assistance in explaining a distribution of the pressure within the pressure chamber. FIG. 24 is an explanatory view of the passageway plate according to this invention.

As shown in FIG. 23, a pressure Q is generated in the pressure chamber by dint of a generated pressure of the piezoelectric actuator 45. A flexure of the passageway plate 41 is produced by this pressure Q. This flexure conduces to a volumetric loss of the ink which should spurt out of the nozzle. For this reason, it is difficult to transform the ink into particles at a high efficiency.

Given is a description of such a passageway plate as to minimize this flexure. As illustrated in FIG. 24, it is assumed that [h] is the thickness of the passageway plate 41, [b] is the width thereof, [l] is the height of the pressure chamber, [Q] is the atmospheric pressure generated in the pressure chamber, [E] is the elastic modulus, and [V] is the ink jet volume. Then, [k] is the coefficient of the loss due to the flexure of the passageway plate 41 with respect to the ink jet volume.

Herein, the loss volume due to the flexure of the passageway plate 41 is indicated by k·V. This loss volume is defined by the following formula:

$$kV \geqq 6 \cdot Qbl^5 / 5 \cdot Eh^3$$

In this formula, the thickness h, the width b, the height l and the elastic modulus E of the passageway plate 41 are selected to establish such a relationship that k = 0.01 or under. If thus selected, the loss volume can be restrained down to 1 % or smaller.

For example, there will be suggested an ink jet printer capable of printing of 360 dpi. Parameter of the pressure chamber of this printer are such that the generated pressure Q = 15 Pa, b = 1 mm, 1 = 100 µm, and h = 92 µm. If a photosensitive resin or the like is employed for this passageway plate 41, even in the case of a resin having the highest elastic modulus, the elastic modulus E is as high as 4 gigapascal (GPa). Accordingly, a loss on the order of 5.78 pl is produced. For this reason, supposing that the ink particle volume needed for forming one dot on the sheet be 100 pl, a pressure chamber's volumetric variation on the order of 105.78 pl is required. Hence, the energy efficiency is not good.

For a shape of this pressure chamber, a member having an elastic modulus of 23 GPa or above is required for setting the volumetric loss to 1 % or under with respect to 100 pl, this volumetric loss being caused by the flexure of the passageway plate 41.

A photosensitive glass, metallic materials such as stainless steel and ceramics can be considered as materials having such an elastic modulus. The elastic modulus E and the loss volume kV thereof are respectively calculated. The photosensitive glass has an elastic modulus E as given by E = 70 GPa, and therefore kV = 0.33 pl. The stainless steel material has an elastic modulus E as given by E = 200 GPa, and hence kV = 0.0036 p1. The elastic modulus E of the ceramics, even in the case of the one having the lowest elastic modulus, is E = 10.000 GPa, and hence kV = 0.0000072 pl.

It is therefore possible to transform the ink into the particles at the high efficiency with a less loss volume by using the materials described above.

This metal member can be worked by an electric casting method, an etching method and a machining method such as a press. The glass can be worked by an ultraviolet ray sensitive glass. The ceramics, before being backed, is worked by machining and thereafter burned, whereby the ceramics can be processed. Patterning at a high accuracy can be attained by applying such a working method.

FIG. 25 is an explanatory view showing another passageway plate.

If the height l of the passageway plate 41 is large, there may be taken such a method that the passageway plate 41 is partitioned into a plurality of subplates 410 which are in turn laminated. That is, it is because a patterning accuracy is more enhanced when the height thereof is small in the case of effecting the patterning on the plate by the above-described working method.

In this example, the passageway plate 41 is partitioned into 3-layered subplates 410. Then, these subplates 410 are joined. Herein, the subplates 410 are, after being laminated, covered with a plating layer 411, thereby actualizing the multi-layered junction.

Further, before effecting the plating junction, the respective plates 410 are laminated, and, thereafter, a temporary junction may be conducted by spot welding and bonding. With this processing, a positional deviation in the plating process can be prevented.

In this way, there is formed the passageway plate in which the loss volume is 1 % or under, whereby the ink can be transformed into the particles at the high efficiency.

Next, the pressurizing plate will be explained.

FIGS. 26A and 26B are explanatory views according to the present invention. FIGS. 27A and 27B are explanatory views showing the respective pressurizing plates.

In the printing head including the multiplicity of nozzles arranged, the pressure chambers and the pressurizing plates are needed corresponding to the number of the nozzles. The pressurizing plate is more capable of independently pressurizing each of the pressure chambers in the case of being divided into the individual nozzles, and hence this is desirable. However, the method of joining the individual independent pressurizing plates per pressure chamber entails a difficulty in terms of manufacturing. Under such circumstances, in this embodiment, there is provided a pressurizing plate easily manufacture and capable of independently individually pressurizing the pressure chamber.

FIG. 26B is a top view of the pressurizing plate 43. FIG. 26A is a sectional view taken along the line X-X' thereof. As illustrated in FIGS. 27A and 27B, the individual pressurizing plate 22 is connected, at the

center of its short side, to a common holding member 430 through thin ribs 431.

As shown in FIG. 27A, a portion, indicated by a broken line in the Figure, of the individual pressurizing plate 22 is pushed by the piezoelectric actuator. In this case, as depicted in FIG. 27B, the ribs 431 are deformed enough to apply the pressure on the ink within the pressure chamber 46.

In this way, the pressurizing plate 22 corresponding to each nozzle is held by the common holding member 430 through at least two pieces of ribs 431 thinner than the pressurizing plate 22, and hence these elements are unified in the form of parts. The joining operation of the pressurizing plate 43 is thereby facilitated.

With the deformation of this rib 431, the stress is concentrated on the rib 431. Therefore, the design is such that the stress is set to a value smaller than a rupture strength of the rib. Further, the rib 431 is tensed in a direction of the long side of the pressurizing plate 22, and this is hard to exert an influence on the displacements of the pressurizing plates 22 above the pressure chambers that are arranged in the short-side direction.

In this pressurizing plate 22, the ribs 431 and the common holding member 430 may be composed of the same members. Employed is a hard resinous film having a Young modulus of several GPa or greater. This resinous film undergoes the patterning by dies cutting and laser working, etc., whereby the pressurizing plate 43 structured as shown in FIG. 26B can be obtained. Polyethyleneterephthalate (PET) and polyethylenenaphthalate (PEN) can be used for a resinous film.

For instance, a PEN film having a thickness of 0.1 mm is employed. A size of the pressure chamber is set to 1.1 mm x 0.19 mm, and an area (within the broken line in FIG. 27B) with which the piezoelectric actuator pushes the pressurizing plate 22 is set to 1 mm x 0.1 mm. Further, a size of the pressurizing plate 22 is set to 1.2 mm x 0.26 mm; a thickness of the elastic layer 42 is set to 10 μm; and a Young modulus of the elastic layer is set to 1.5×10^6 Pa. Under these conditions, a stress calculation is conducted by a finite element method.

According to this calculation, a width of the rib 431 is 0.04 mm, and a length thereof is 0.02 mm. In this case, the stress becomes 3×10^7 Pa. Accordingly, the rupture strength of the rib material is 2×10^8 Pa, and hence the rib is sufficiently durable against the stress.

As illustrated in FIGS. 26A and 26B, the pressurizing plate 43 is allowed to serve as a wall of the common ink chamber 48. With this arrangement, the common ink chamber 48 may be, as in the same way with the pressure chamber 46, manufactured in an opened state. That is, the common ink chamber 48 is also sealed together by bonding of the pressurizing plate 43. Accordingly, with the bonding of the pressurizing plate 22, the common ink chamber 48 can be also simultaneously formed.

FIG. 28 is an explanatory view showing another pressurizing plate.

As illustrated in FIG. 28, the thickness of the rib 431 is smaller than those of the pressurizing plate 22 and of the common holding member 430. When jetting out a predetermined volume of the ink out of the nozzle by pressurizing the ink within the pressure chamber 46, it is required that the pressurizing plate 22 be rigid enough not to deform easily. Namely, a displacement efficiency of the piezoelectric actuator for pressurization is required to be increased to spurt a predetermined quantity of ink with an irreducible minimum displacement quantity.

For this purpose, it is required that the pressurizing plate 22 be rigid and hard to deform. With this arrangement, it follows that mainly the elastic layer between the pressurizing plate 22 and the pressure chamber is deformed. When making the pressurizing plate 22 more rigid, the integrally formed rib 431 also becomes more rigid. Therefore, the rib 431 is not easy to deform.

Then, the sectional area is reduced by decreasing the thickness of the rib 431. Consequently, the rib 431 is easy to deform, and the rigid pressurizing plate 22 is obtained.

In the case of making use of the piezoelectric actuator in a d_{31} displacement mode, it is desirable that such a pressurizing plate be composed of an insulator. The piezoelectric actuator in the d_{31} displacement mode is, as in the case of the piezoelectric actuator shown in FIG. 18, provided with the electrodes on its side surfaces. A front end of the piezoelectric actuator is bonded to the pressurizing plate 22. For this purpose, in the case of the pressurizing plate 22 being metallic, there exists a danger of being short-circuited. Therefore, the pressurizing plate 22 is composed of, desirably, the insulator. For example, the resinous film is a good insulator and therefore preferable as a material of the pressurizing plate 2.

As a method of preventing this electrical short-circuiting, there can be also considered a method forming no electrode in the vicinity of the front end of the piezoelectric actuator. For securing a predetermined active length for the piezoelectric actuator, the length of the piezoelectric actuator is elongated, correspondingly. This is disadvantageous in terms of manufacturing.

Further, it is more advantageous in terms of manufacturing that the pressurizing plate 22 is transparent. When bonding the pressure chamber to the pressurizing plate 22 with an elastic bonding agent, it is required that the thickness of the elastic layer after being hardened be kept to a predetermined value (10 μm - 20 μm). Attention is paid to the pressurization when being bonded. An over-pressurization leads to a

bulge of the bonding agent, whereas an under-pressurization brings about incomplete bonding. For this reason, when examining the bonding conditions, and if the pressurizing plate 22 is transparent, the bonding state can be grasped.

FIGS. 29A and 29B are explanatory views each showing another pressurizing plate according to this invention. As illustrated in FIGS. 29A and 29B, a thin film member 432 is provided on a portion constituting the wall of the common holding member 430 which forms the common ink chamber 48. This thin film member 432 in turn forms a pressure damper.

When the pressurizing plate 22 pressurizes the ink within the pressure chamber 46, the ink spurts out of the nozzle. Simultaneously with this, an pressure of the ink is generated also in the common ink chamber 48 from the ink supply port 47. At this time, the pressure of the common ink chamber 48 rises enough to induce pressure fluctuations in other pressure chamber 46. This may be a cause for a cross talk.

For preventing the pressure fluctuations, the pressure damper is required to be provided in the common ink chamber 48. In accordance with this embodiment, a part of the common holding member 430 undergoes laser beam machining or etching machining, thereby forming the pressure damper constructed of the thin film member 432.

This pressure damper is designed in the following manner.

When an equi-distribution load p is applied on the pressure damper having the Young modulus E, the length l, the width w and the thickness t, the volumetric displacement V is expressed by the following formula:

$$V = 0.151\ plw^5 / Et^3$$

From this formula, the acoustic capacity Cd of the pressure damper is given by the following formula:

$$Cd = \Delta V / \Delta p = 0.151\ 1w^5 / Et^3$$

On the other hand, the acoustic capacity Cn of the nozzle is on the order of $1/10^{16}$ - $1/10^{18}$. Hence, for restraining the pressure fluctuation when performing 10-30 nozzle simultaneous jetting downs to 1% or under, it is required that the acoustic capacity Cd of the pressure damper be on the order of $1/10^{13}$ - $1/10^{15}$.

Accordingly, the Young modulus E, the length l, the width w and the thickness t of the pressure damper are determined so that the acoustic capacity Cd of the pressure damper is on the order of $1/10^{13}$ - $1/10^{15}$.

FIG. 30 is a view illustrating a configuration of another pressure damper.

As illustrated in FIG. 30, a hole is formed in a part of the wall of the pressurizing plate 43 constituting the common ink chamber 48. A thin film 610 is stuck by use of a one-pack silicon rubber 611 so as to seal this hole. Thus, the pressure damper is formed.

The film 610 is composed of the PET. The PET has a Young modulus of 4×10^9 Pa, a thickness of 6 μm and a surface size of 3.764×0.46 mm². In this head, the cross talk is examined. As a result of this, both a velocity fluctuation and a jetting rate fluctuation are on the order of ± 10% or under.

This film 610 may involve the use of, in addition to the PET, high polymer materials such as PI (polyimide) and metallic materials such as Ni, Al, SUS, etc..

FIG. 31 is a view showing a configuration of still another pressure damper.

The hole is formed in a part of the wall of the pressurizing plate 43 constituting the common ink chamber 48. The thin film 610 is provided so as to seal this hole. This film 610 is formed such that the PET having a thickness of 10 μm is coated with a hot-melt bonding agent (ethylene-vinyl acetate copolymer) up to 2 μm. This film 610 is fused by heating under conditions, i.e., at 150°C, at 5 kg/cm² and for 5 sec, thus forming the pressure damper.

FIG. 32 is a view illustrating a configuration of yet another pressure damper.

The wall of the common ink chamber 48 is fitted with a pressure damper plate 613 provided in the pressurizing plate 43 together with the pressurizing plate 22. The pressurizing plate 43 employed herein is constructed in such a way that a PI film having a thickness of 5 μm is provided with the SUS pressurizing plate 22, corresponding to the pressure chamber. In this embodiment, the film corresponds to the portion, constituting the common ink chamber, of the pressurizing plate 43, and, therefore, the pressure damper can be formed without working the pressurizing plate 43.

Next, the piezoelectric actuator 45 will be explained.

FIG. 33 is a perspective view of the piezoelectric actuator. FIG. 34 is a plan view illustrating a lead frame for the piezoelectric actuator. FIG. 35 is a perspective view of the lead frame of FIG. 34. FIG. 36 is a constructive view illustrating how the piezoelectric actuator of the present invention is assembled. FIG. 37 is a view of assistance in explaining a structure of the electrode thereof.

The piezoelectric actuator is required to be formed corresponding to each nozzle. Generally, this type of piezoelectric actuator is formed of multi-layered piezoelectric bodies laminated on each other. A method of laminating the multi-layered piezoelectric bodies entails high manufacturing costs. This is a problem inherent in this method. Accordingly, it is desirable that the piezoelectric actuator assuming a configuration corresponding to each nozzle be composed of a single-layered piezoelectric body.

On the other hand, in the ink jet head including the above-mentioned elastic layer, the displacement quantity of the piezoelectric actuator may be small. Therefore, the single-layered piezoelectric body is usable. As shown in FIG. 33, a single-layered piezoelectric block 45 is formed with a multiplicity of piezo-

electric elements 451 corresponding to the individual nozzles.

This piezoelectric element 451 is formed as follows. To begin with, a multiplicity of notches are formed in the piezoelectric block 45 from an arrowed direction A by use of a dicing saw, thus forming the respective piezoelectric elements 451. With this arrangement, the piezoelectric elements 451 take a one-row comb-like configuration on the whole. Next, the central portion of the piezoelectric block 45 is notched from an arrowed direction B, thus forming a groove 450. With this formation, a group of two-row piezoelectric elements 451 is formed.

In this way, the nozzle 2-row piezoelectric elements 451 can be formed by notching the piezoelectric block 45. This piezoelectric actuator 45 can be manufactured at lower costs than the lamination type piezoelectric body because of each piezoelectric element 451 being based on the single-layered structure. Further, the piezoelectric body itself takes the comb-like configuration, and hence it is possible to attain a high strength and a high integration.

The thus structured piezoelectric actuator has a structure that is easy to take out the electrodes. That is, as illustrated in FIG. 37, electrodes 451-1, 451-2 are formed on both surfaces of the piezoelectric element 451 by plating. The electrodes are thereby formed on the side surfaces of each piezoelectric element 451, and the drive in the d_{31} mode can be performed.

Taking out the electrodes, as shown in FIGS. 34 and 35, involves the use of a lead frame 50. More specifically, as shown in FIG. 34, a common electrode 500 is provided at the center thereof, and besides, a plurality of individual electrodes 501, 502 extending from the center are provided. As illustrated in FIG. 34, the lead frame 50 is cut in a cut position CUT-1, thus providing an independent lead frame. Thereafter, as depicted in FIG. 35, this lead frame 50 is folded in accordance with a width of the piezoelectric block 45.

Next, the lead frame 50 is cut in a cut position CUT-2. In the lead frame 50, the tips of the common electrode 500 are separated from the tips of the individual electrodes 501. Thereafter, as illustrated in FIG. 36, the common electrode 500 of the lead frame 50 is fitted into the central groove 450 of the piezoelectric block 45, and, then, the lead frame 50 is lowered down to the lower edge of the groove 450 and temporarily fixed thereto.

At this time, as shown in FIG. 37, the positioning thereof is performed so that the tip of the common electrode 500 contacts a first electrode 451-1 of each piezo electric element 451, and the tip of each individual electrode 501 contacts a second electrode 451-2 of each piezoelectric element 451. The tips of this common electrode 500 and of the individual electrodes 501 are coated with solders beforehand.

In this state, the piezoelectric block 45 is moved under a near infrared-ray lamp. Then, a focus of the lamp is set on the contact area of the electrode, and this area is irradiated with a beam of light from the near infrared-ray lamp. At this time, the near infrared-ray lamp is desirably of a focus type so as to exert no influence on the piezoelectric element. Also, if irradiated for a long time, the piezoelectric element is to be deteriorated, and, therefore, an irradiation time is desirably 1 sec - 60 sec.

In this manner, the solder previously coated on the lead frame 50 is melted by the irradiation of the light beam from the near infrared-ray lamp. As a result, the tip of the common electrode 500 is bonded to the first electrode 451-1 of each piezoelectric element 451, while the tip of each individual electrode 501 is bonded to the second electrode 451-2 of each piezoelectric element 451.

Thereafter, the lead frame 50 shown in FIG. 34 is cut in a cut position CUT-3. If cut in this way, the lead can be led out by making use of the two side surfaces of the piezoelectric block 45, and down-sizing of the piezoelectric actuator 45 can be thereby attained. Further, the electrodes are bonded by use of the non-contact near infrared-ray lamp, and therefore the bonding can be more easily carried out than by a method using a soldering iron.

FIG. 38 is a cross-sectional view illustrating the multi-nozzle head. FIG. 39 is a side view of the multi-nozzle head of this invention.

As depicted in FIG. 38, the piezoelectric actuator 45 constructed as described above is held by the holder 44. Then, each piezoelectric element 451 of the piezoelectric actuator 45 is bonded to the pressurizing plate 22 of the pressurizing plate 43. Also, as shown in FIG. 39, because of the nozzles arranged in four rows, the two piezoelectric actuators 45 are disposed in parallel.

FIG. 40 is an explanatory view showing another lead frame. FIG. 41 is an explanatory view illustrating a connecting state of another lead frame of this invention. FIG. 42 is a view illustrating an electrode structure thereof.

As depicted in FIG. 40, there is prepared the lead frame 50 including a common electrode 512 and individual electrodes 513 that are connected to each other. This lead frame 50 is cut in a cut position CUT. Subsequently, this common electrode 512 and the individual electrodes 513 are fitted into the above-described piezoelectric block 45. At this time, as shown in FIG. 42, the positioning thereof is performed so that the tip of the common electrode 500 contacts the first electrode 451-1 of each piezo electric element 451, and the tip of each individual electrode 501 contacts the second electrode 451-2 of each piezoelectric element 451. The tips of this common electrode 500 and of the individual electrodes 501 are coated with solders beforehand.

further, as shown in FIG. 41, both of the common

electrode 512 and the individual electrodes 512 are taken out on the same surface of the piezoelectric block 45. Then, the common electrode 512 and the individual electrodes 513 are superposed up and down. An insulating material such as plastics is interposed between these two electrodes, thus insulating the two electrodes.

On this occasion, the respective lead frames 512, 513 are coated with the solders nd temporarily secured in target bonding portions of the piezoelectric block 45. Thereafter, these portions are irradiated with the light beams from the near infrared-ray lamp, thus bonding them. Further, the lead frame 512 of the common electrode is connected via a connecting wire 515 to leads 514. When thus connected, the leads can be led by use of the side surfaces of the piezoelectric block 45.

In addition to the embodiments discussed above, the following modifications can be carried out.

First, the method of forming the elastic layer explained in FIGS. 20 through 22 is applicable to the head including the wall member explained in FIG. 2 but constructed of only the elastic layer. Second, similarly, the pressurizing plate explained with reference to FIG. 26 onward is also applicable to the head including the wall member explained in FIG. 2 but constructed of only the elastic layer.

The present invention has been discussed so far by way of the embodiments. A variety of modifications can be, however, carried out within the scope of the claims.

As discussed above, firstly, instead of the vibration plate, the pressurizing plate 22 which is hard to bend is driven by the piezoelectric actuator 23, and the wall member 24 is deformed. Hence, the fatigue breaking derived from the vibration can be prevented, and, at the same time, the occurrence of the satellite particles can be also prevented. Secondly, the pressurizing plate 22 is extruded without bending the vibration plate, and therefore the ink jetting energy can be enhanced. Thirdly, besides, since the piezoelectric actuator is fixed to the pressurizing plate 22, the negative polarity drive can be effected, thereby making it possible to jet out the ink at high efficiency.

Claims

1. An ink jet head for jetting out ink in a pressure chamber by applying pressure to said pressure chamber, which is adapted for accommodating the ink, said ink jet head comprising:
   a nozzle plate including a nozzle for jetting out the ink;
   a pressurizing plate provided in parallel to said nozzle plate;
   a wall member, exhibiting elasticity, for forming said pressure chamber by connecting said nozzle plate to said pressurizing plate; and
   a piezoelectric actuator, fixed to said pressurizing plate, for driving said pressurizing plate so as to deform said wall member.

2. An ink jet head according to claim 1, wherein said wall member is comprised of an elastic member.

3. An ink jet head according to claim 1, wherein said wall member includes a member provided on the side of said nozzle plate and having a high rigidity and also an elastic member provided on the side of said pressurizing plate and having a low rigidity.

4. An ink jet head according to claim 3, wherein said high-rigidity member is formed with a supply port for supplying the ink to said pressure chamber.

5. An ink jet head according to claim 3 or claim 4, wherein said low-rigidity member is formed with a supply port for supplying the ink to said pressure chamber.

6. An ink jet head according to claim 2, 3, 4 or 5, wherein said elastic member is formed with a slit for preventing interference with an adjacent pressure chamber.

7. An ink jet head according to any preceding claim, wherein said piezoelectric actuator is negative-polarity-driven.

8. An ink jet head according to any one of claims 2 to 6, wherein said elastic member is composed of a member having a Young modulus falling within a range of 1×10^5 Pa - 1×10^9 Pa.

9. An ink jet head according to any one of claims 2 to 6 or 8, wherein said elastic member is formed by hardening after a liquid elastic material has been printed on said nozzle plate or on one surface of said high rigidity member.

10. An ink jet head according to any one of claims 2 to 6 or 8 or 9, wherein said elastic member is composed of a bonding agent exhibiting a low rigidity.

11. An ink jet head according to any one of claims 2 to 6 or 8 to 10, wherein said elastic member is constructed of a bellows.

12. An ink jet head according to claim 11, wherein the bellows exhibits a low rigidity.

13. An ink jet head according to any preceding claim, wherein said piezoelectric actuator is provided between said nozzle plate and said pressurizing

plate.

14. An ink jet head according to any preceding claim, further comprising a common holding member for holding said pressurizing plate and a rib for connecting said pressurizing plate to said common holding member.

FIG. 1A

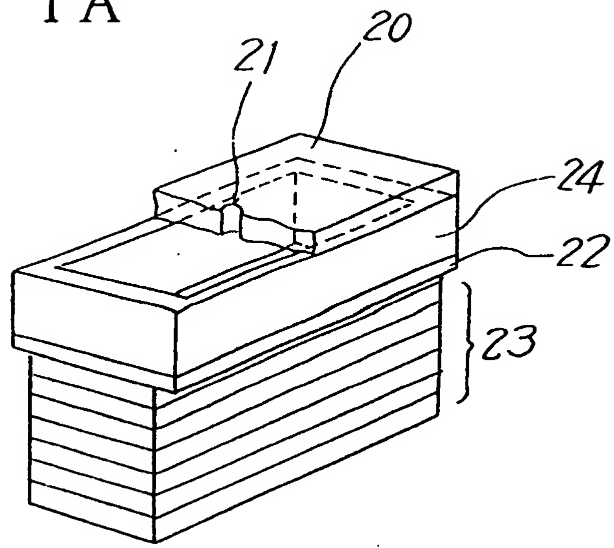


FIG. 1B

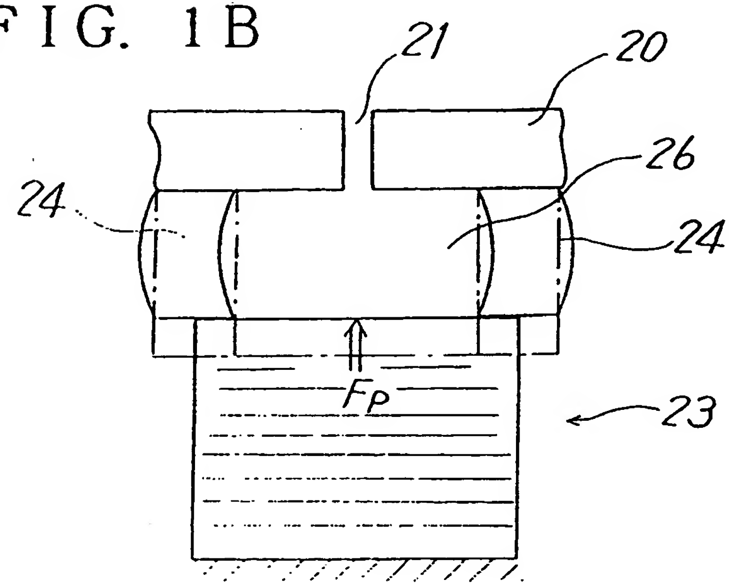


FIG. 2

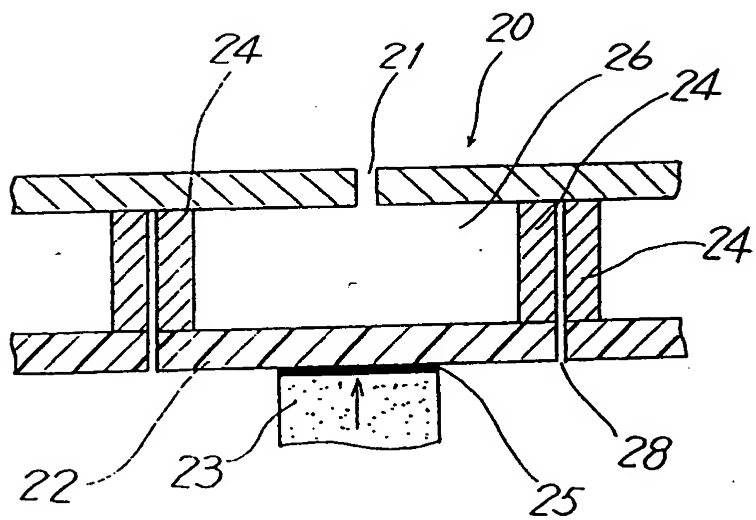


FIG. 3

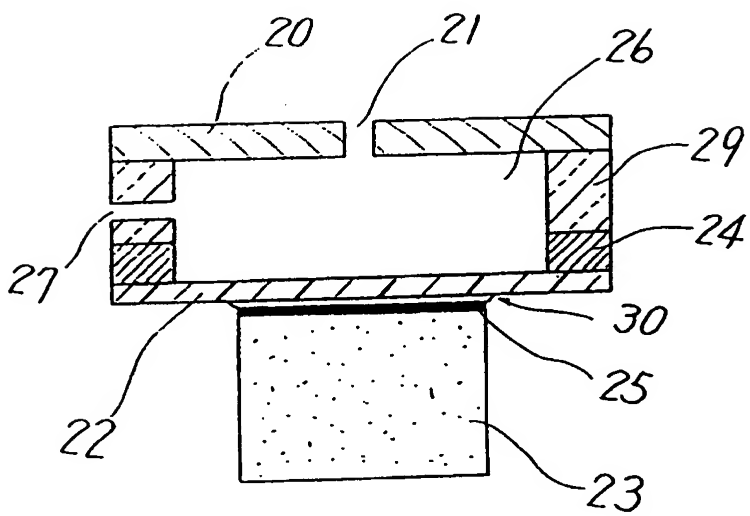


FIG. 4A

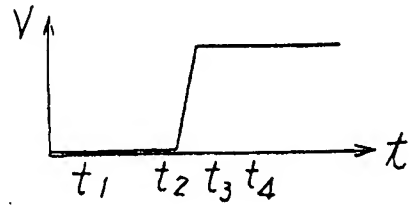


FIG. 4B

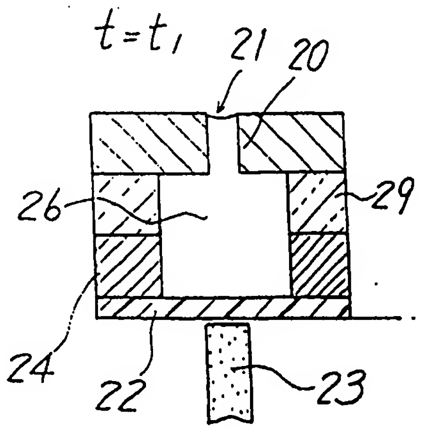


FIG. 4C

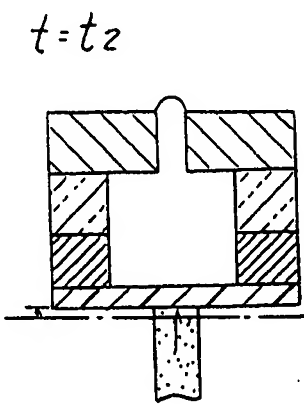


FIG. 4D

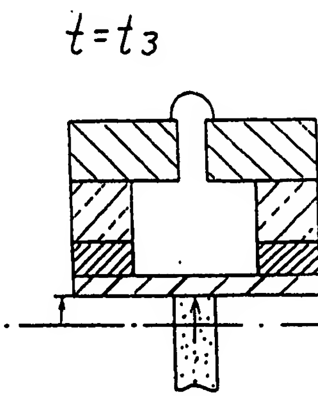
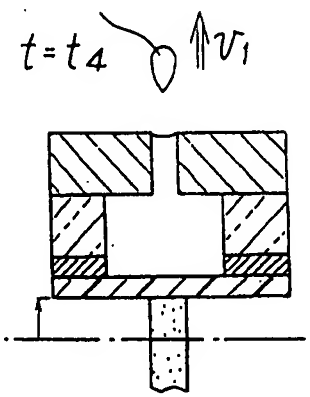


FIG. 4E



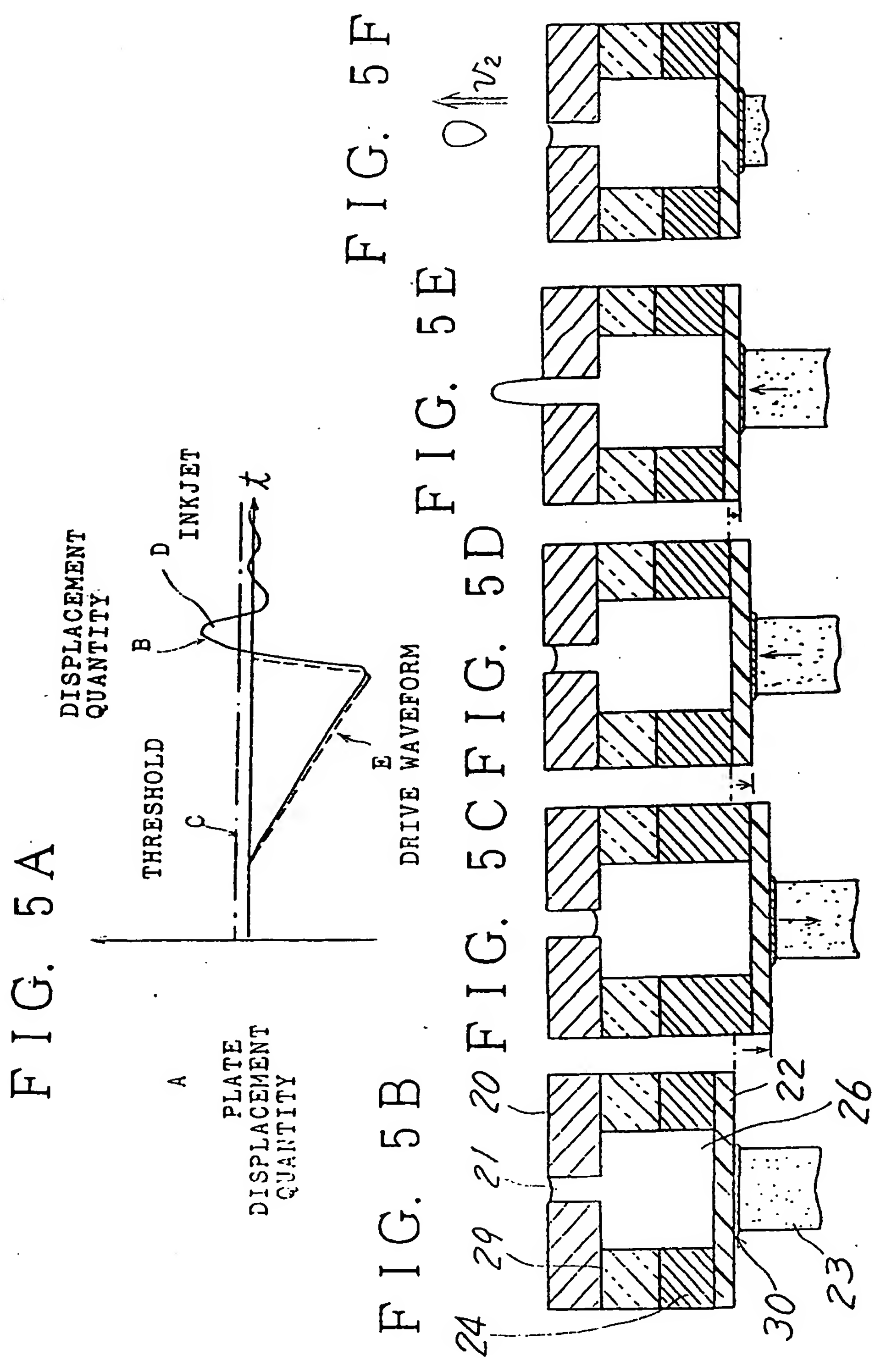


FIG. 5A

FIG. 5B

FIG. 5C

FIG. 5D

FIG. 5E

FIG. 5F

FIG. 6

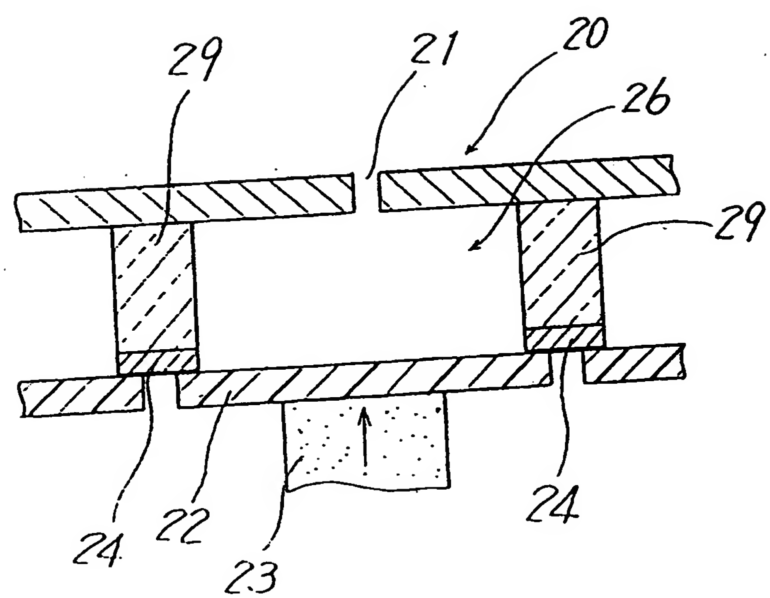


FIG. 7

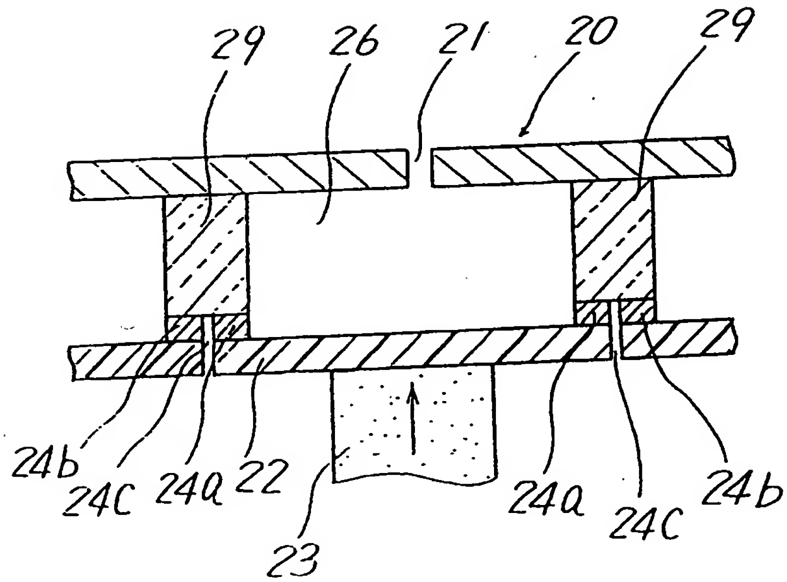


FIG. 8

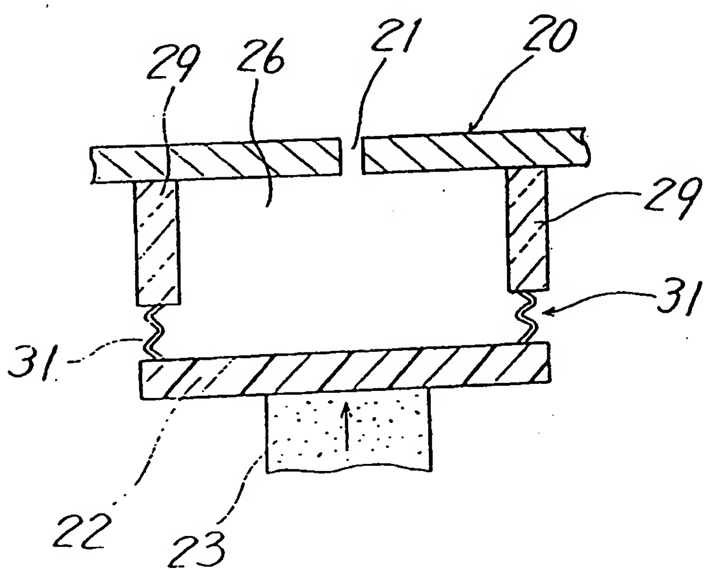


FIG. 9A

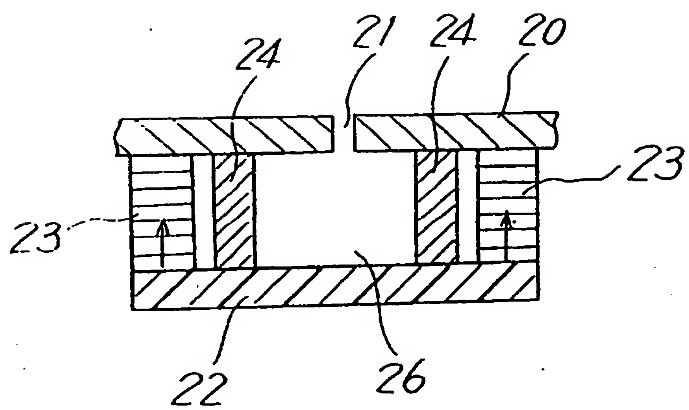


FIG. 9B

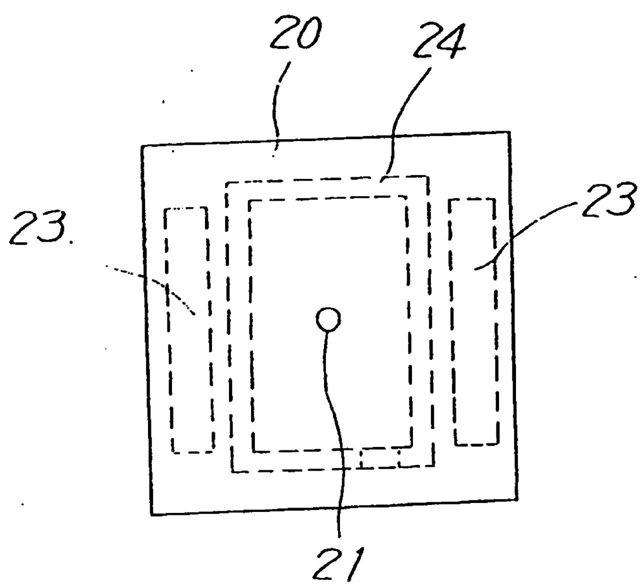


FIG. 10A

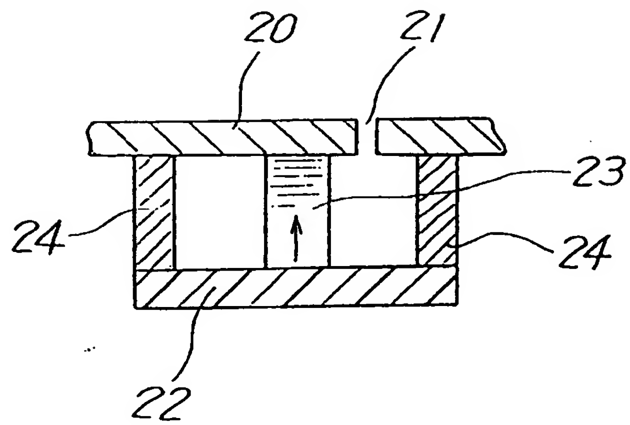


FIG. 10B

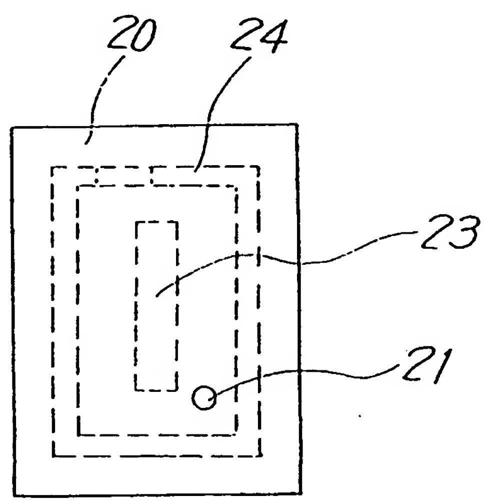


FIG. 11A

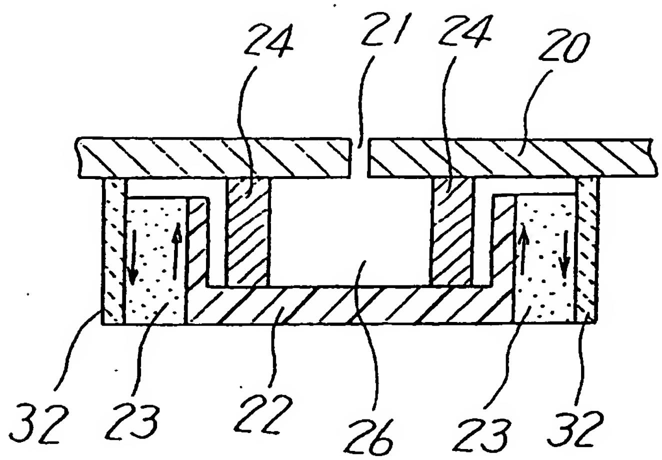


FIG. 11B

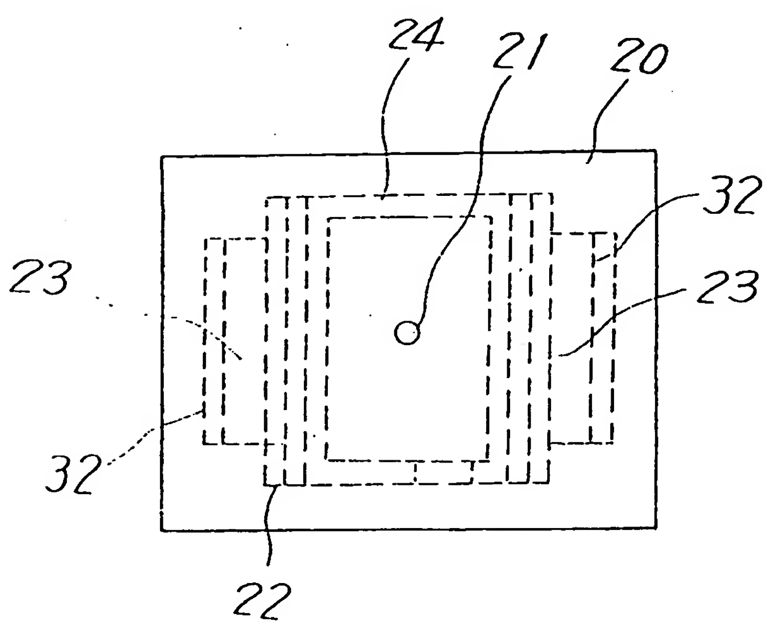


FIG. 12

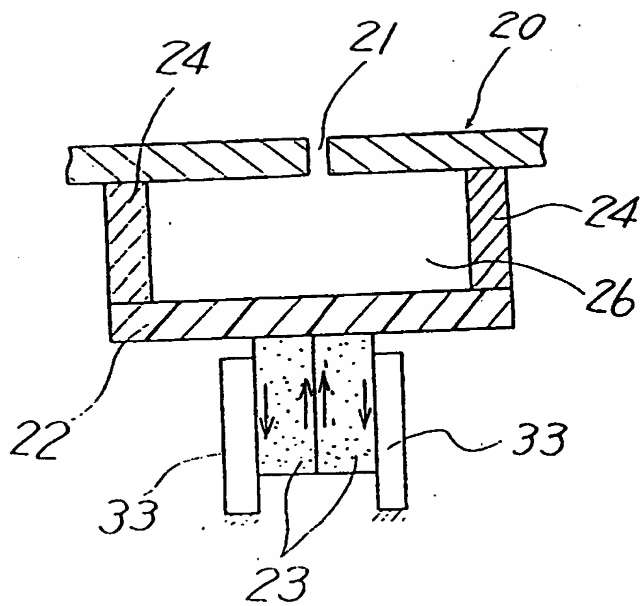


FIG. 13A

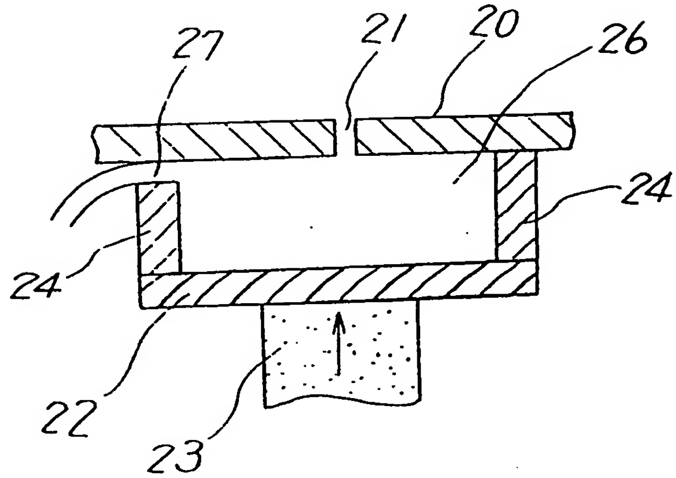


FIG. 13B

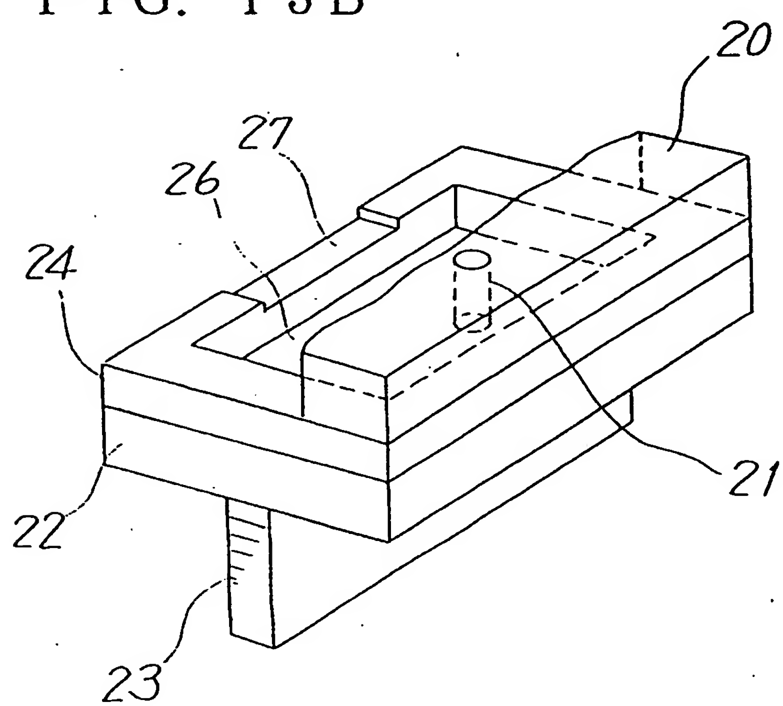


FIG. 14A

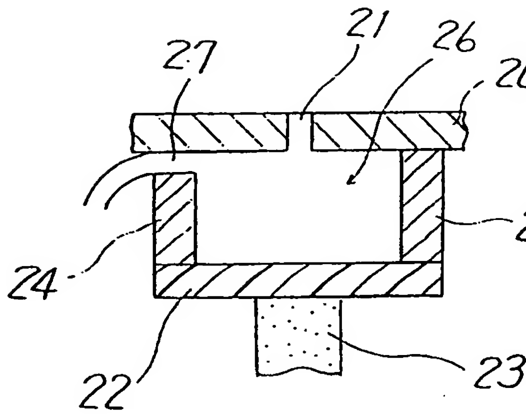


FIG. 14B

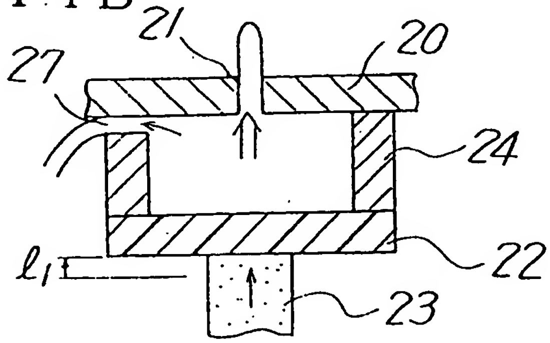


FIG. 14C

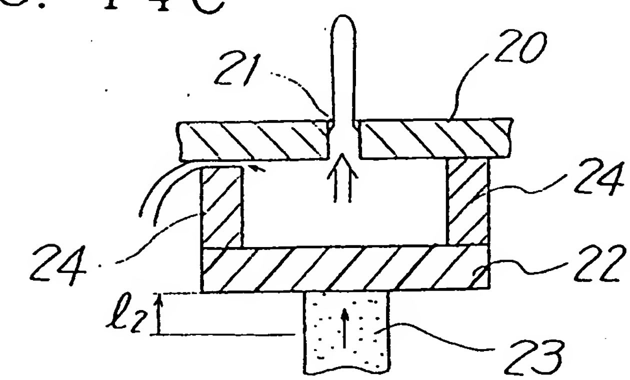


FIG. 15A

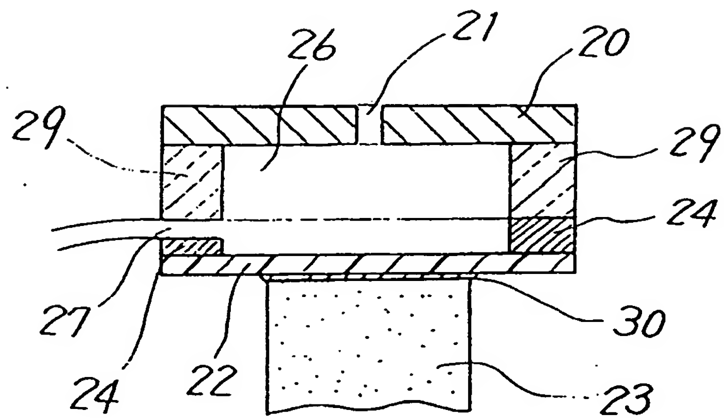


FIG. 15B

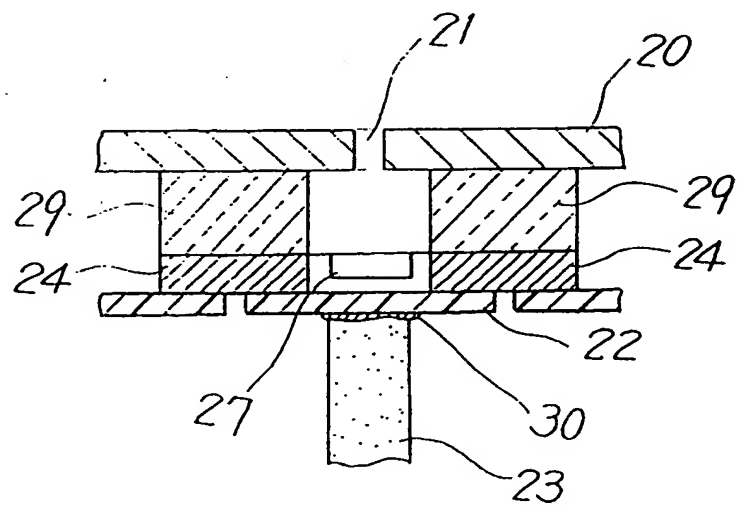


FIG. 16A

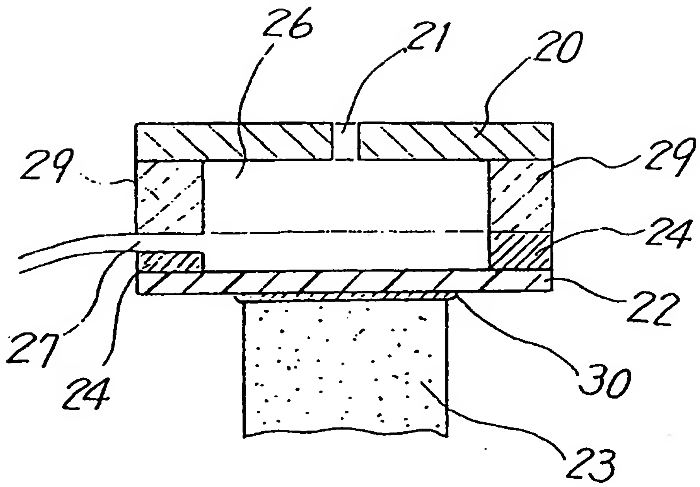


FIG. 16B

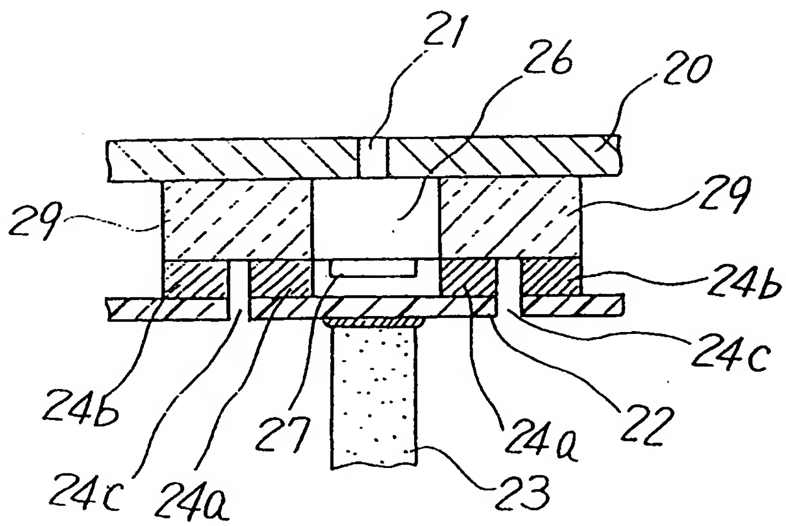


FIG. 17

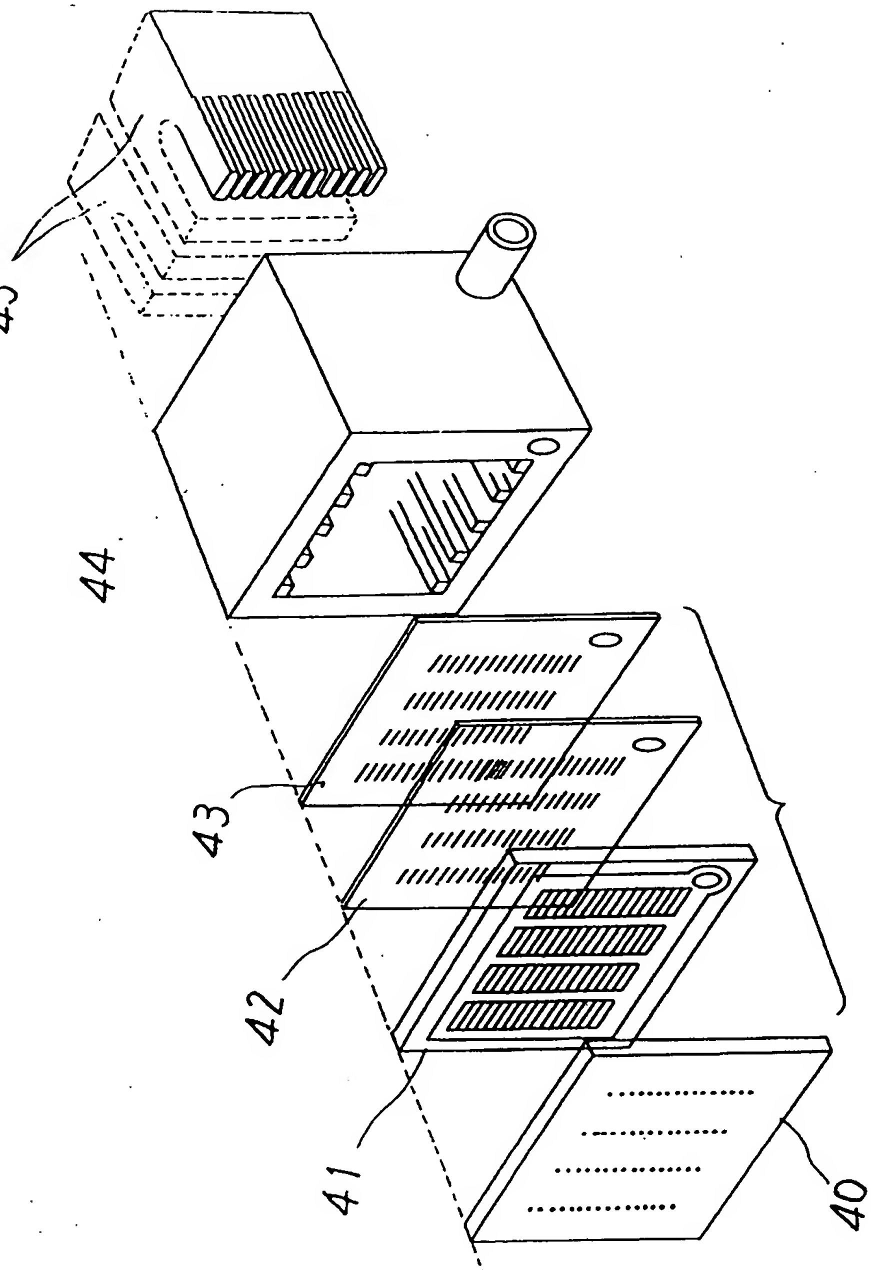


FIG. 18

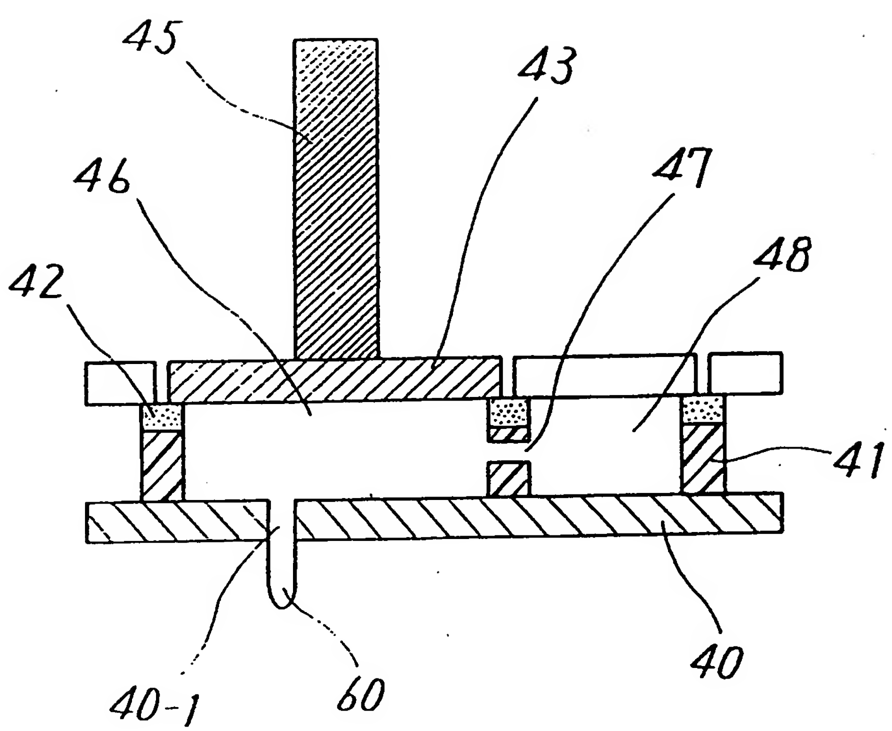
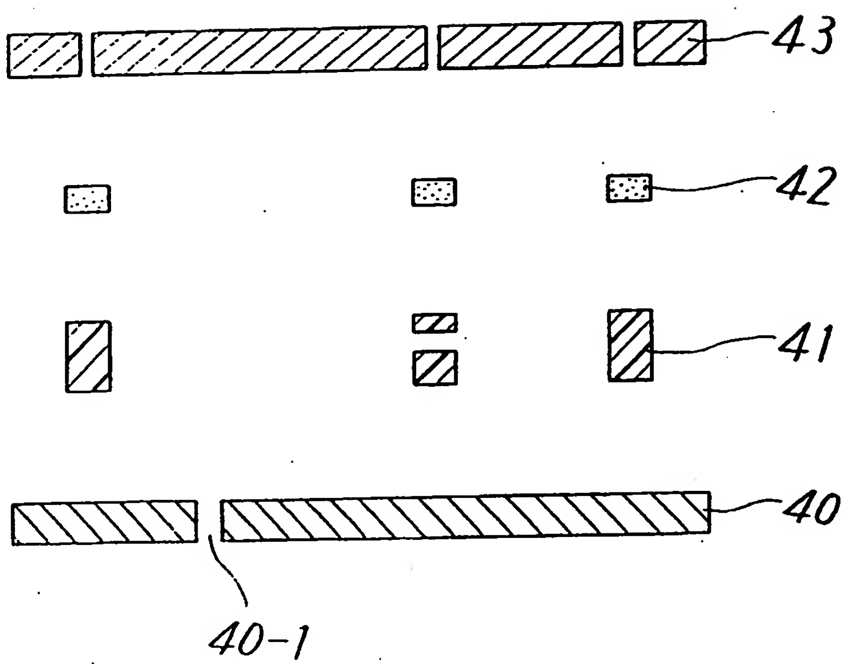


FIG. 19



F I G. 2 0

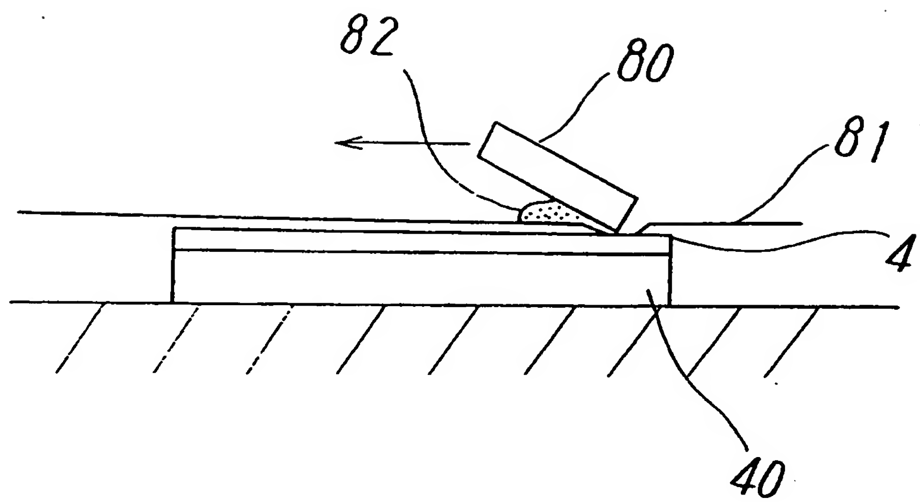
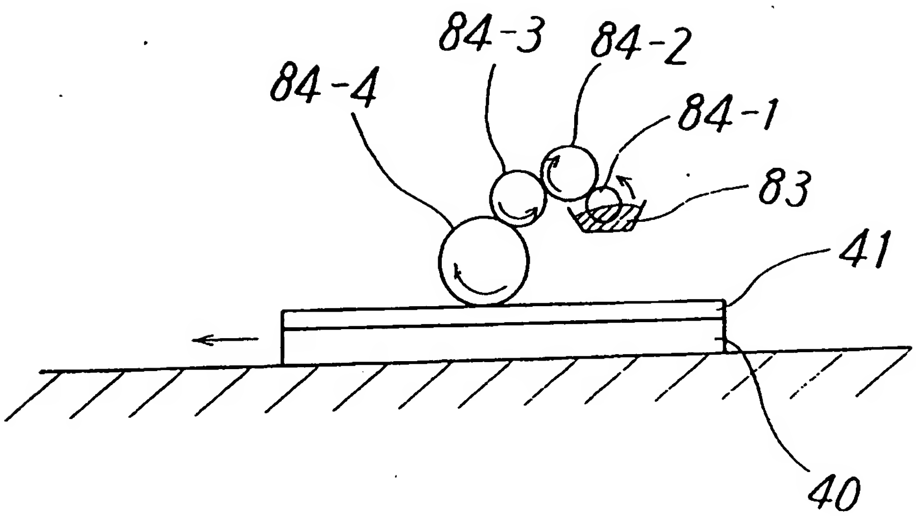


FIG. 21



F I G. 2 2

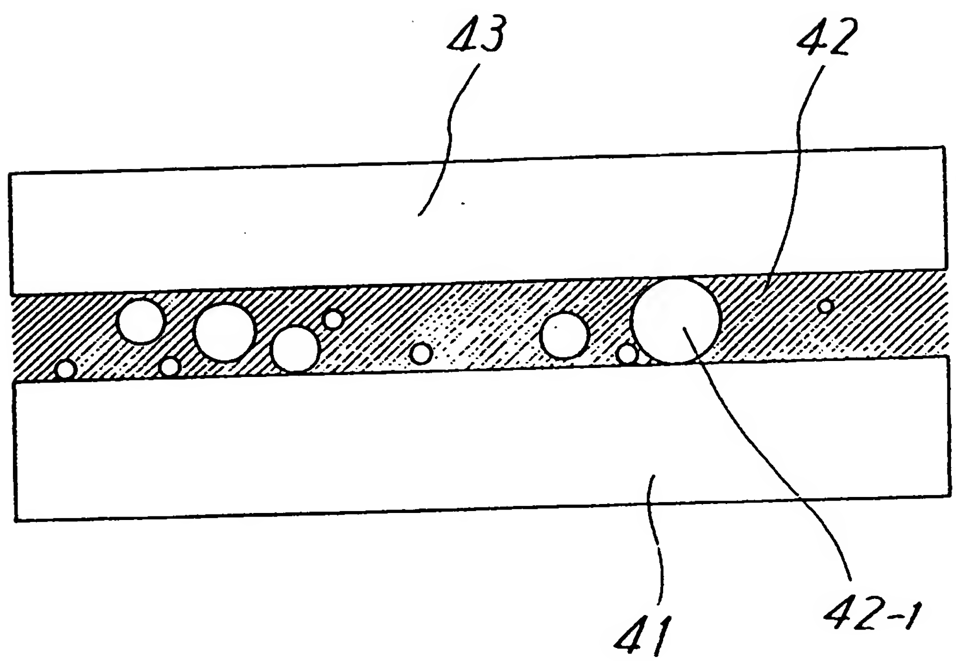


FIG. 23

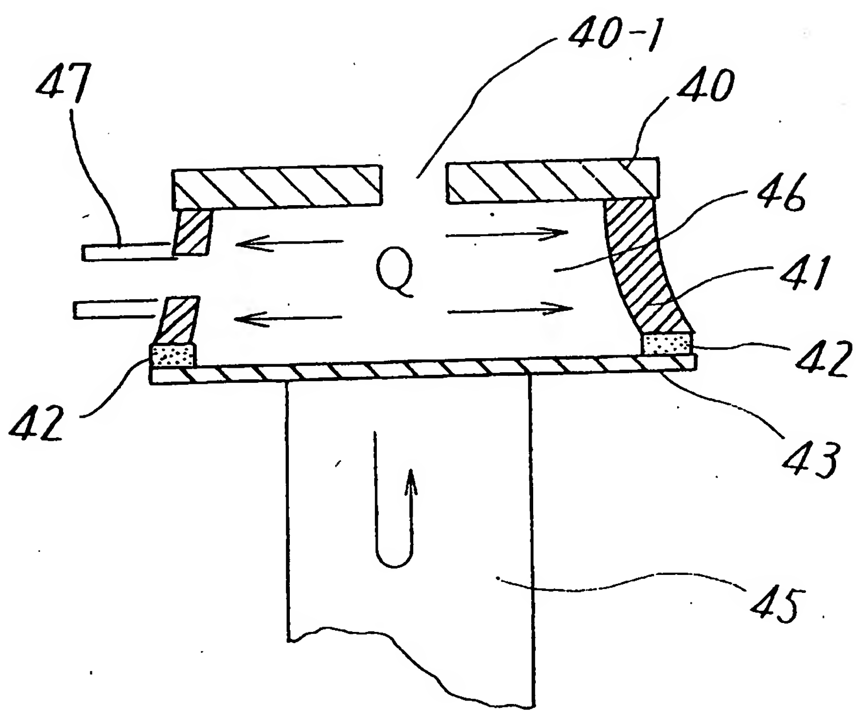


FIG. 24

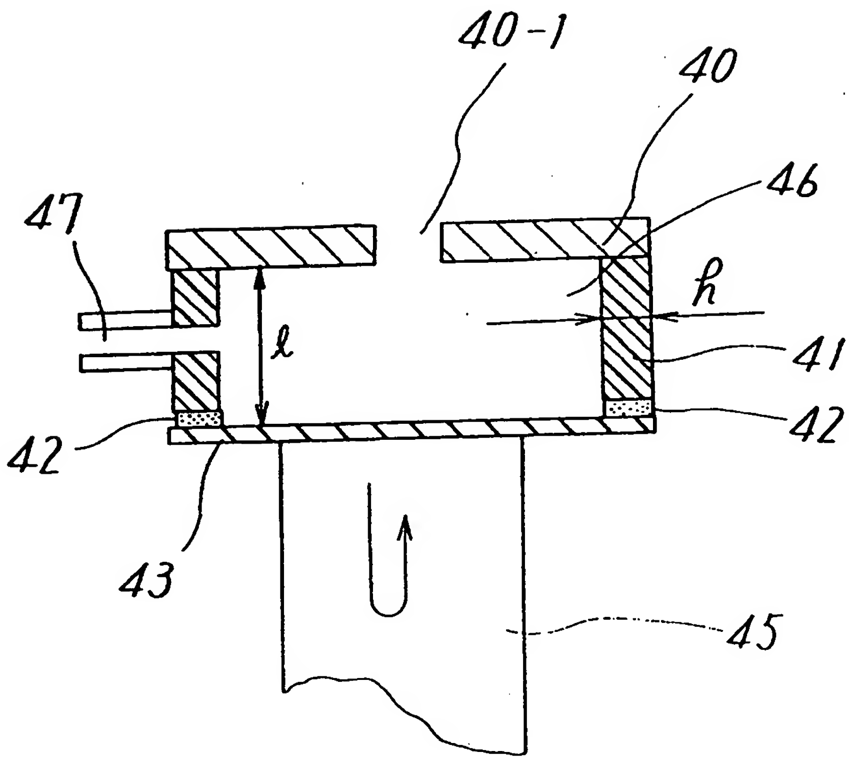


FIG. 25

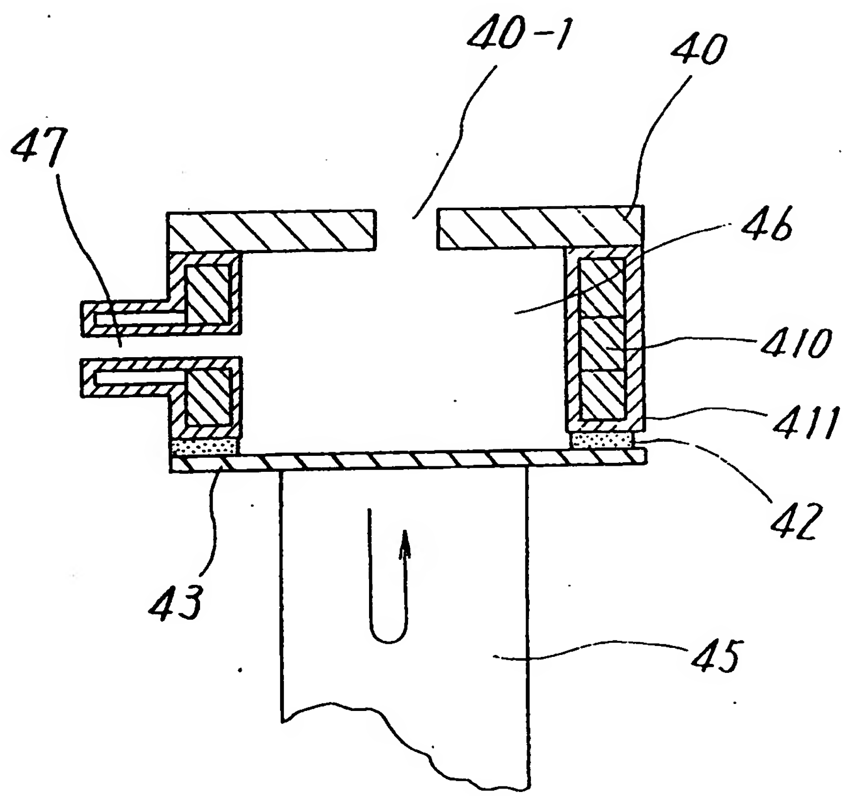


FIG. 26A

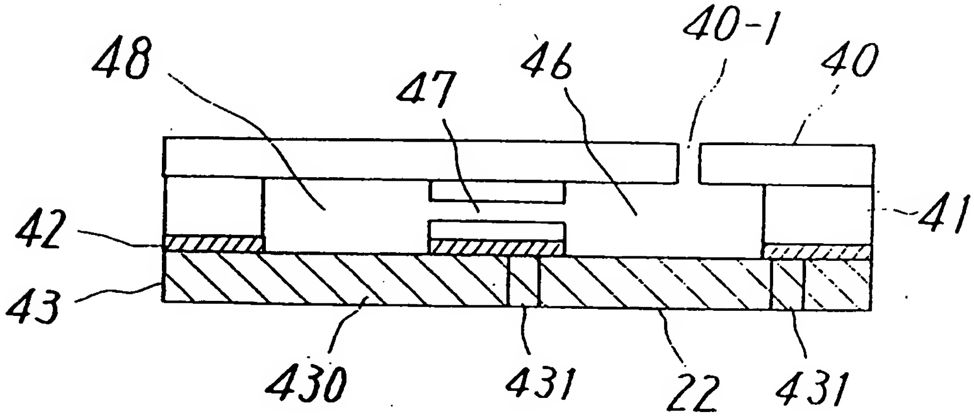


FIG. 26B

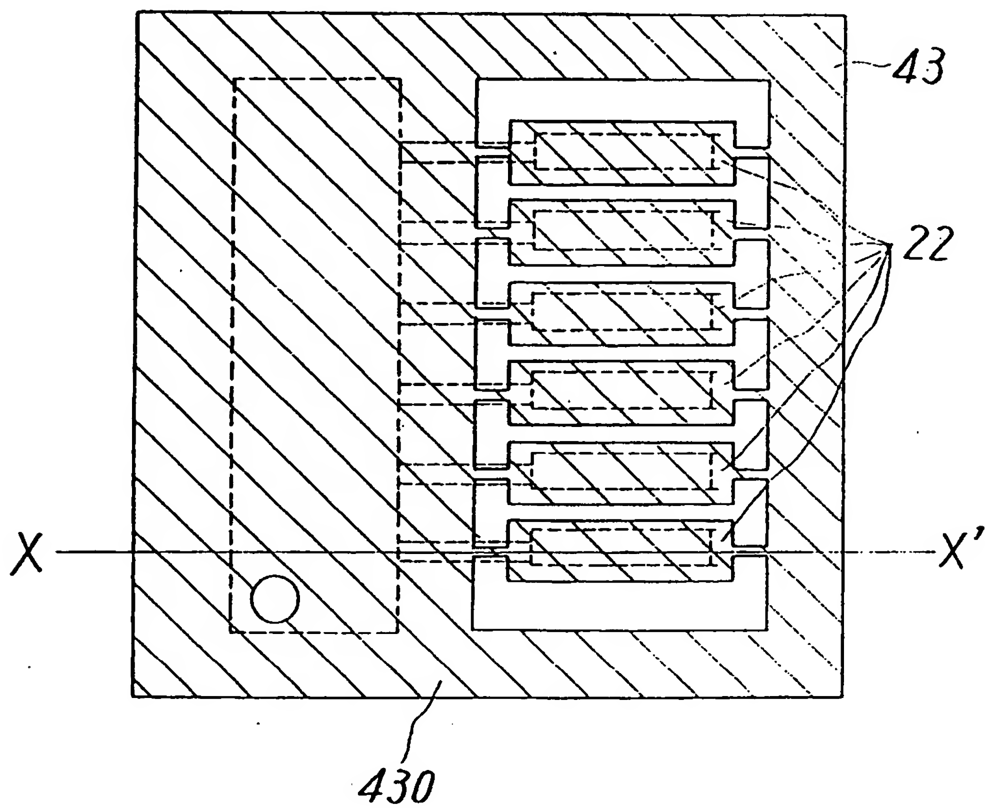


FIG. 27A

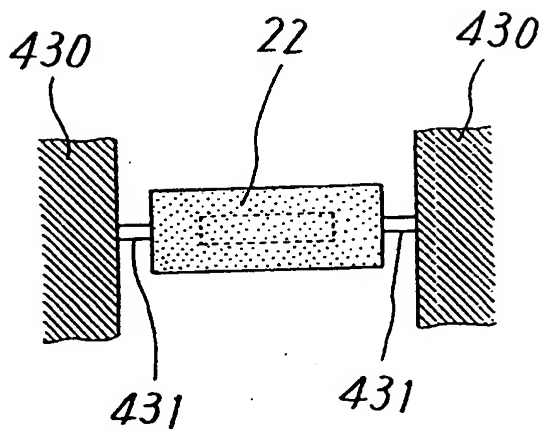


FIG. 27B

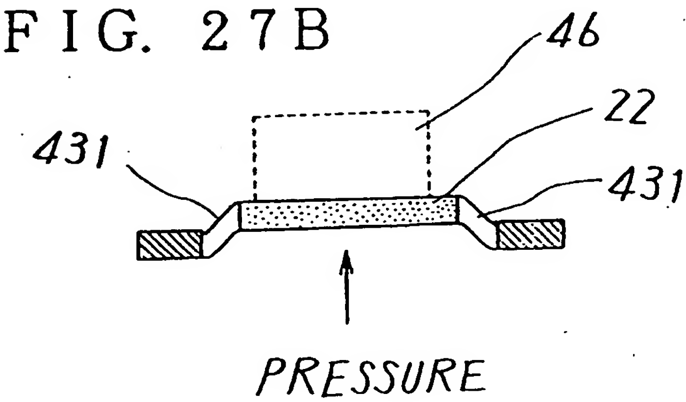


FIG. 28

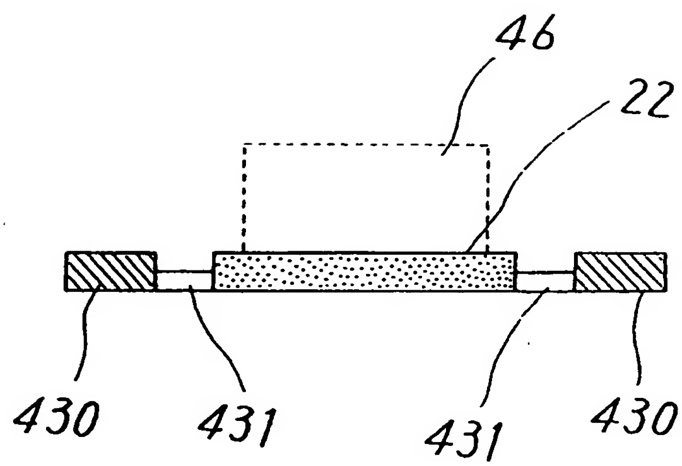


FIG. 29A

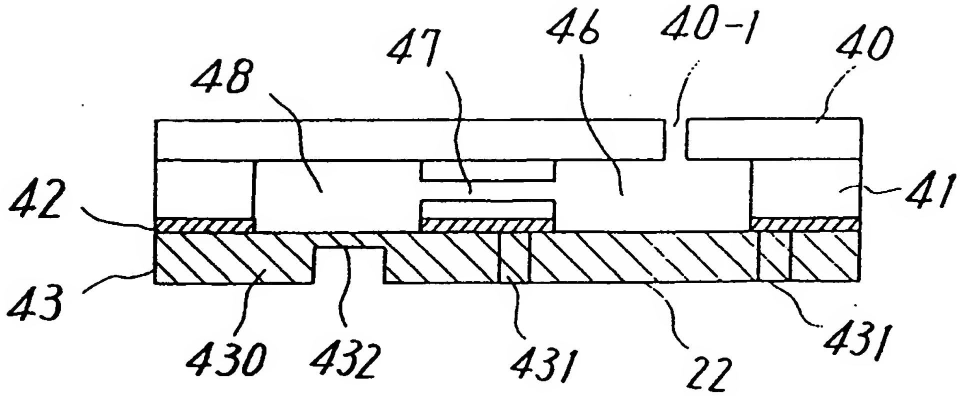


FIG. 29B

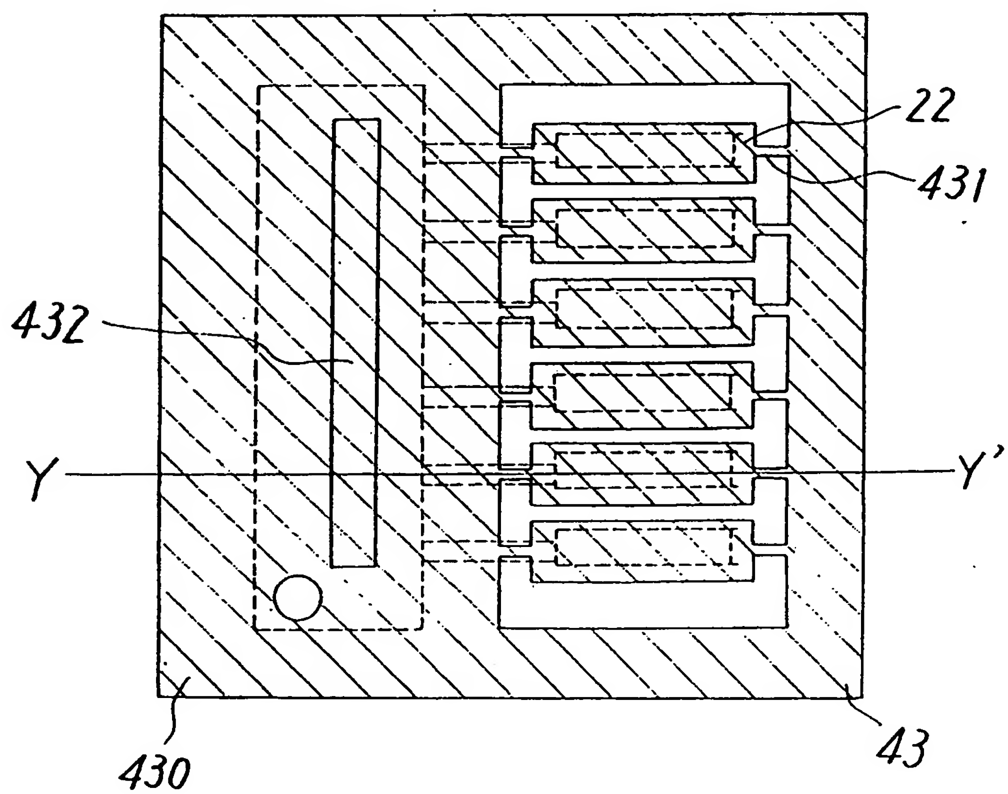


FIG. 30

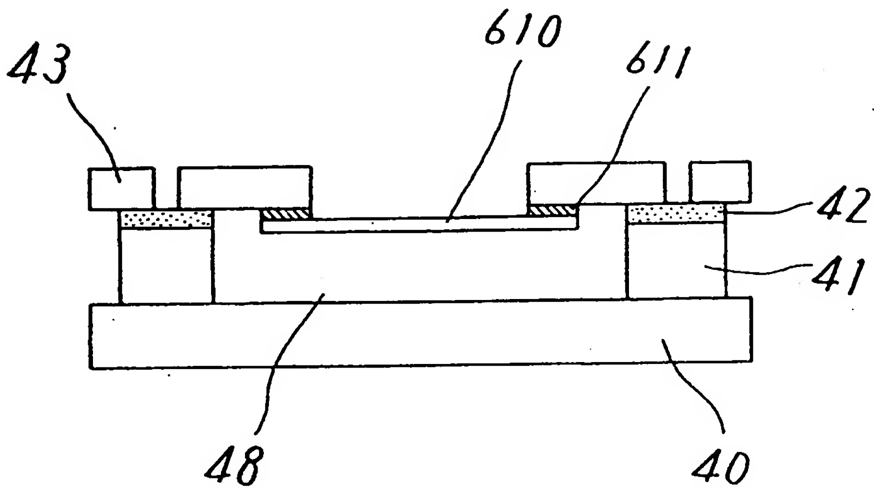


FIG. 31

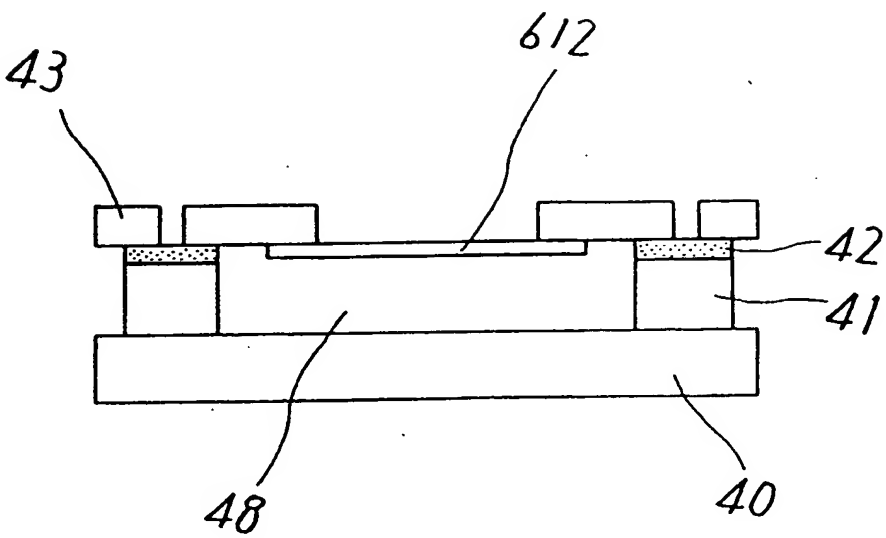


FIG. 32

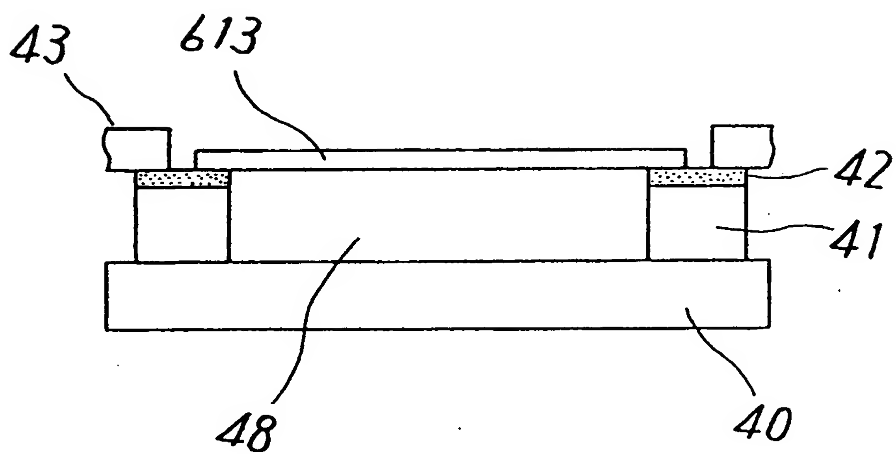
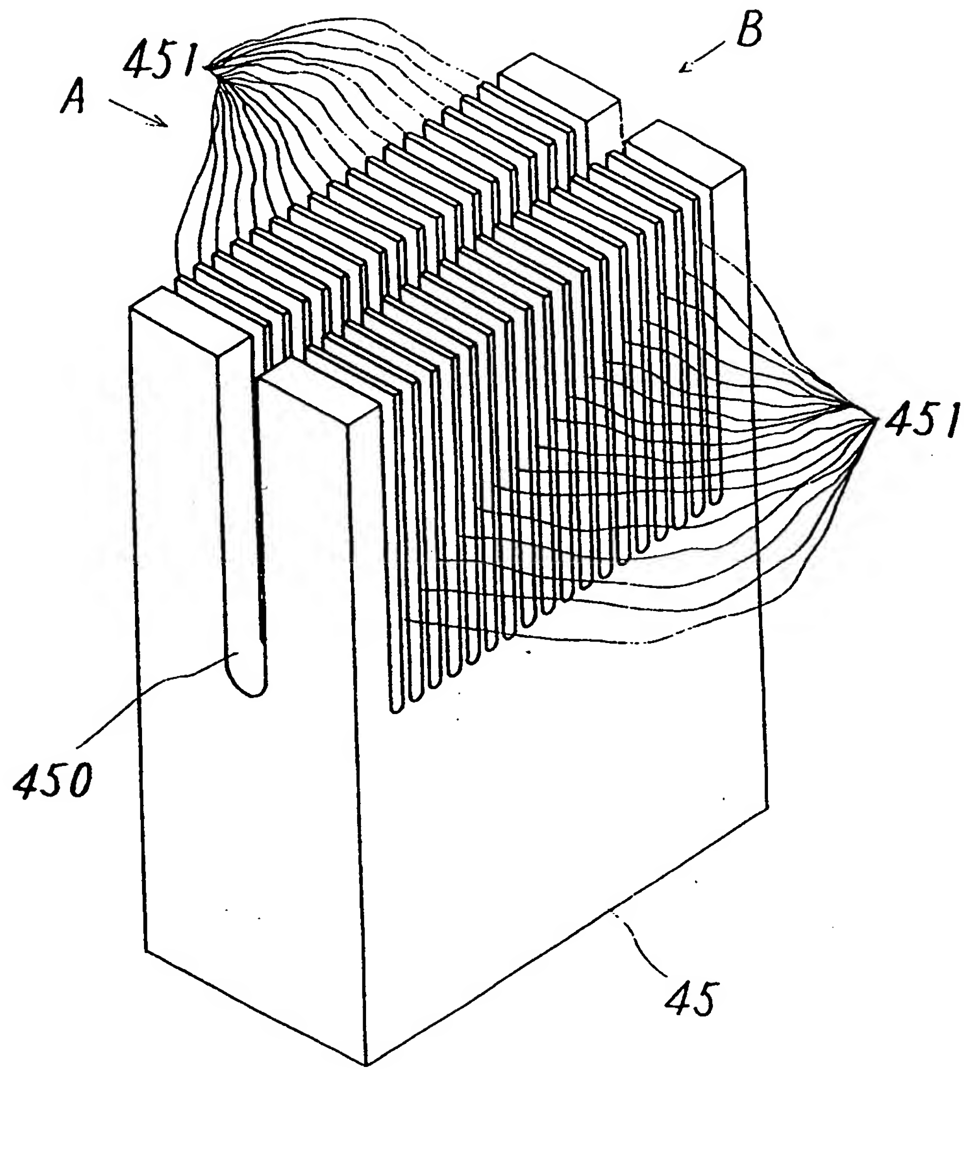


FIG. 33



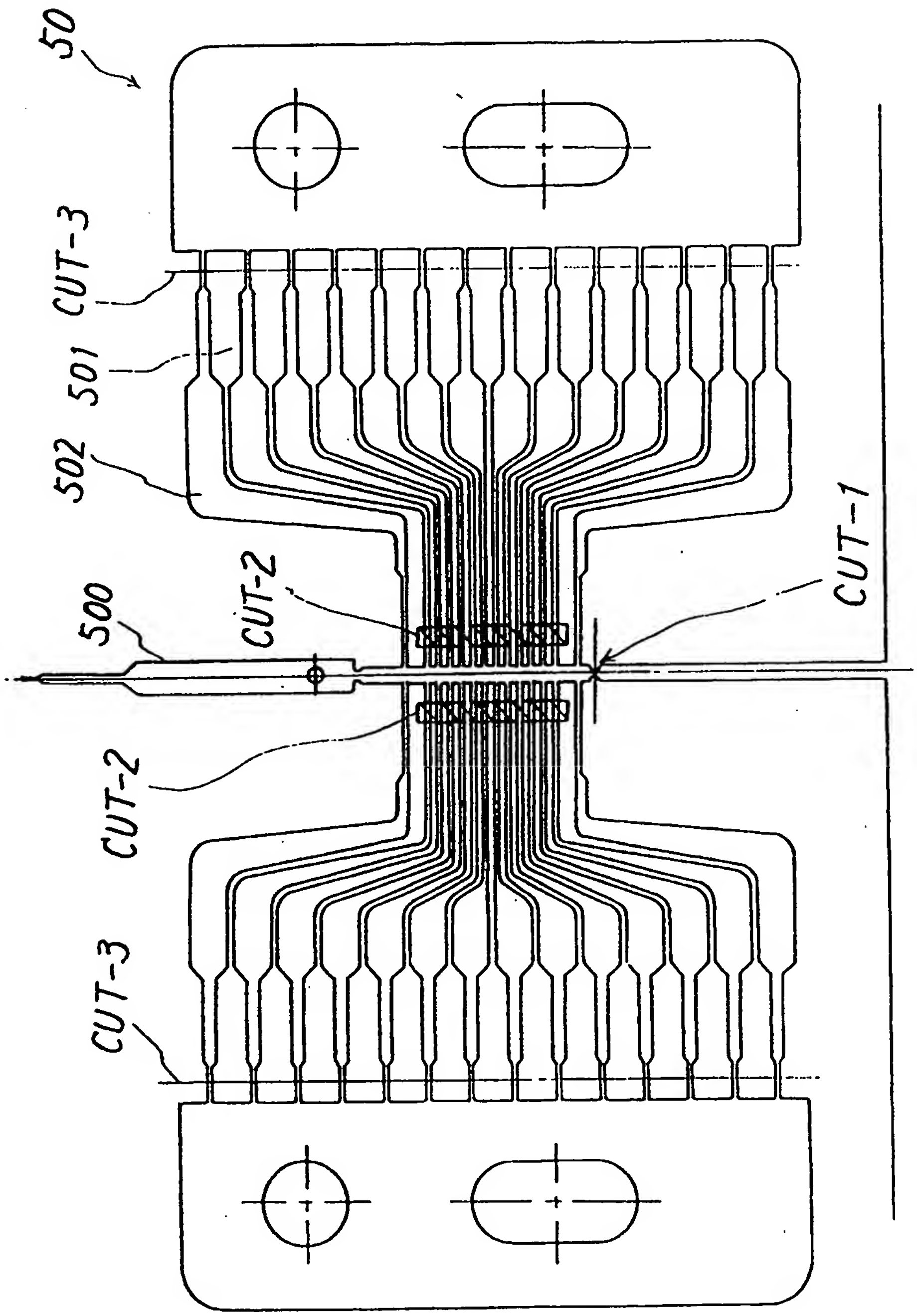


FIG. 34

FIG. 35

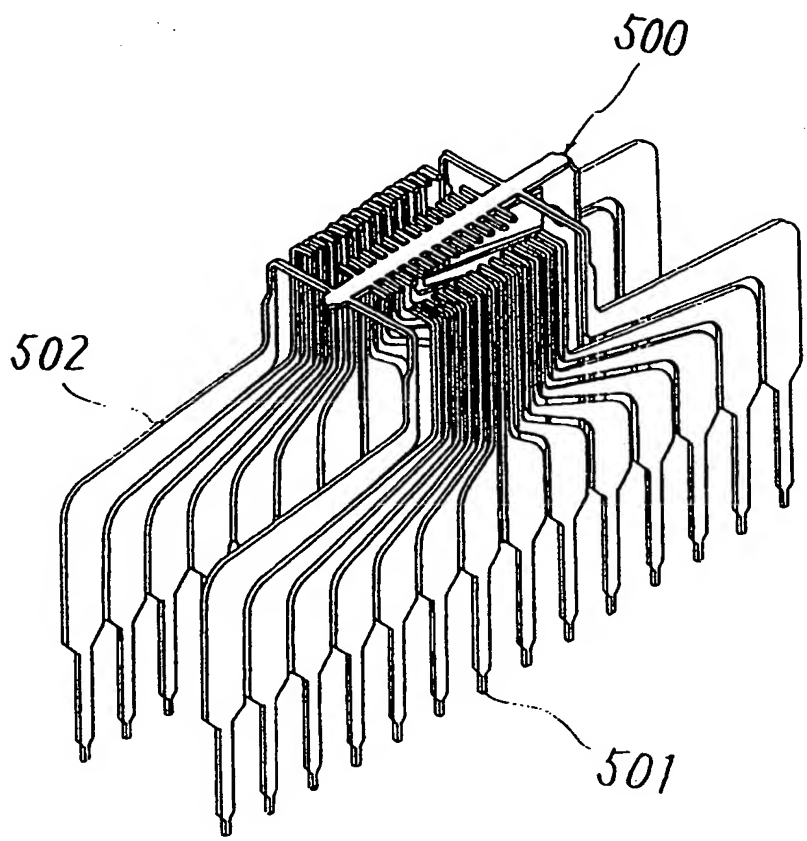


FIG. 36

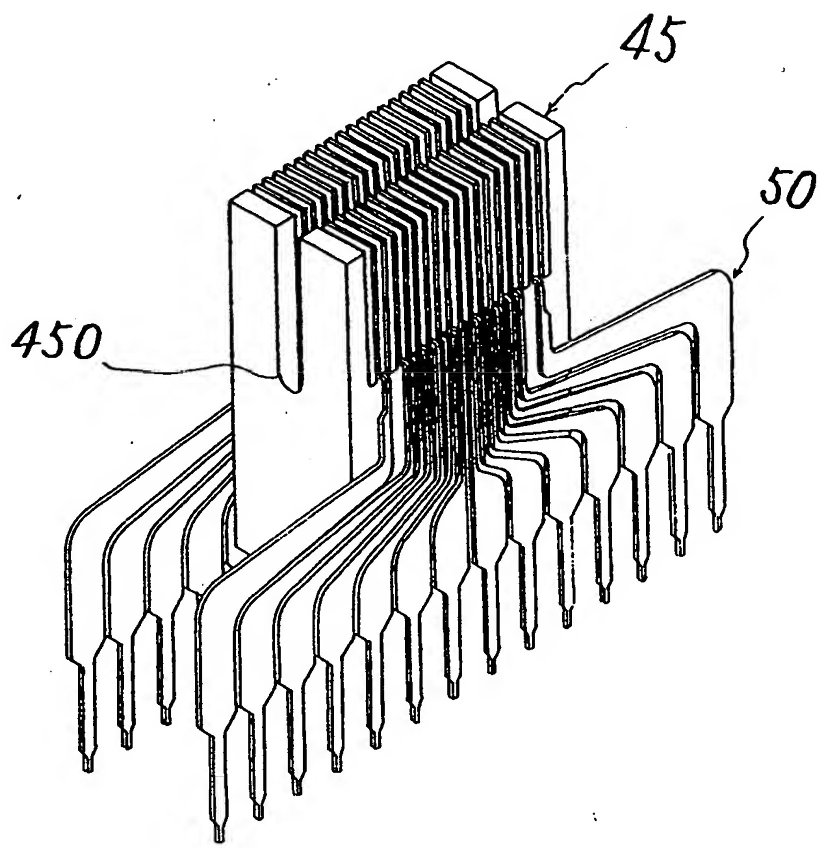


FIG. 37

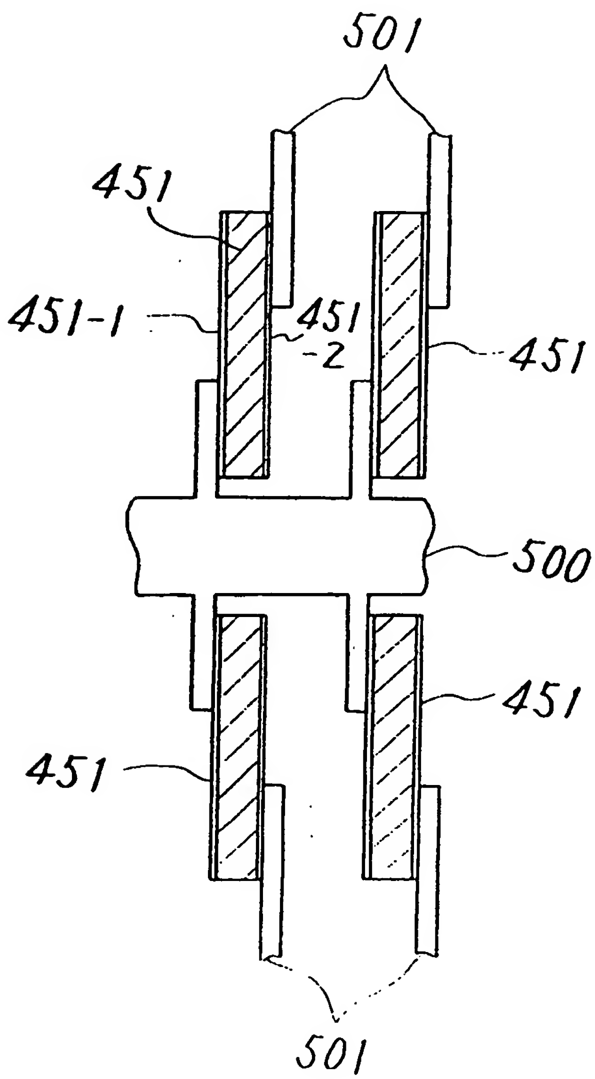


FIG. 38

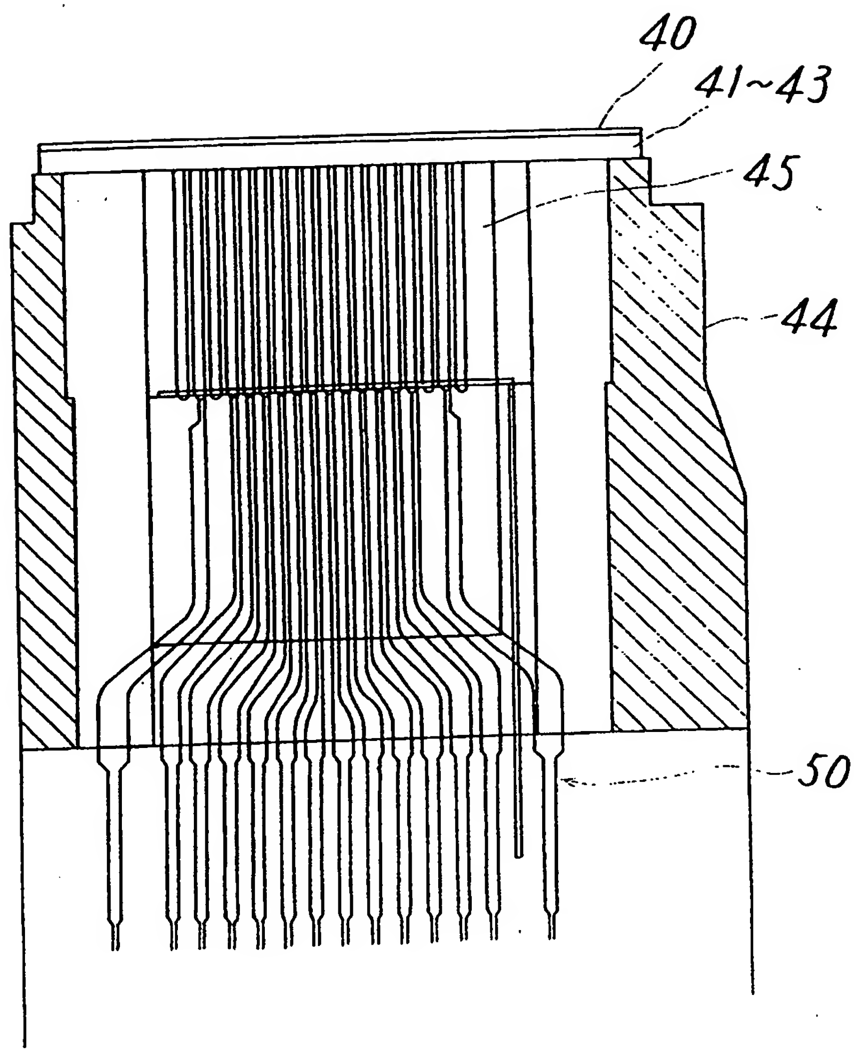


FIG. 39

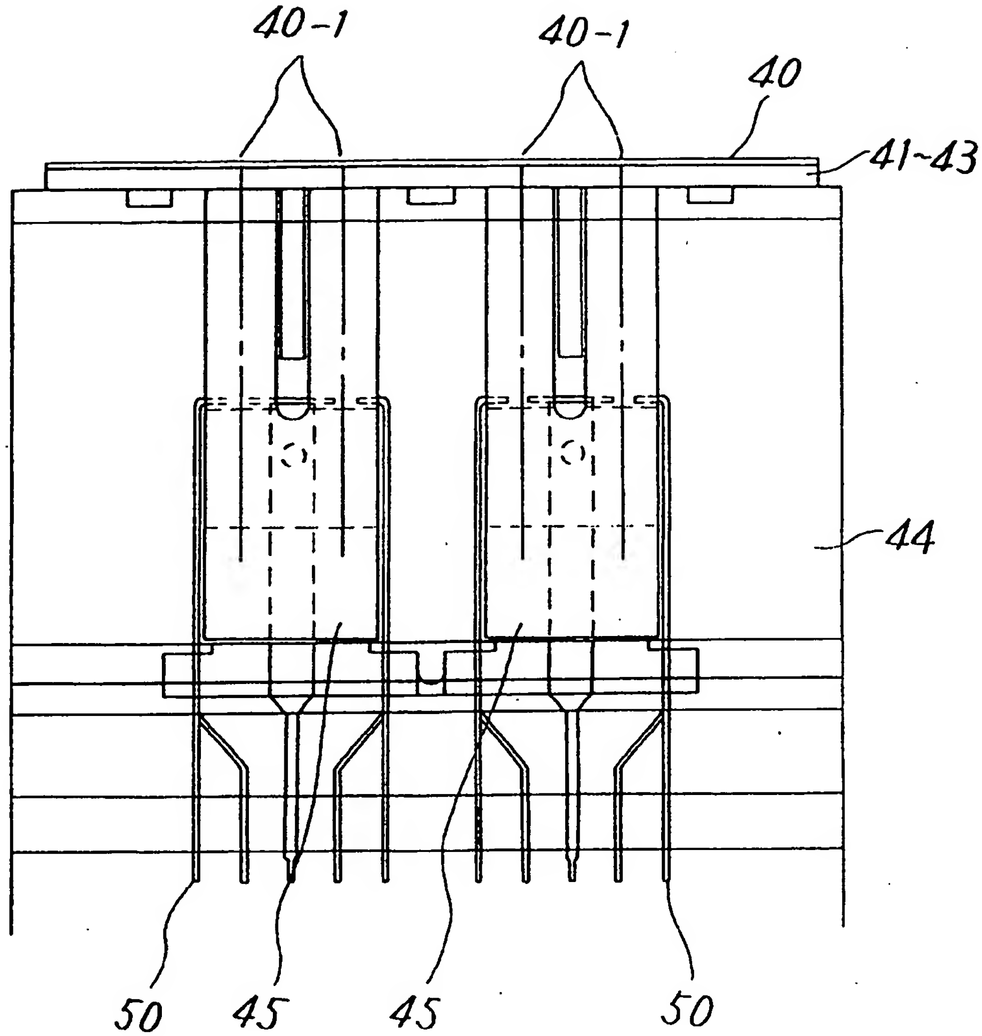


FIG. 40

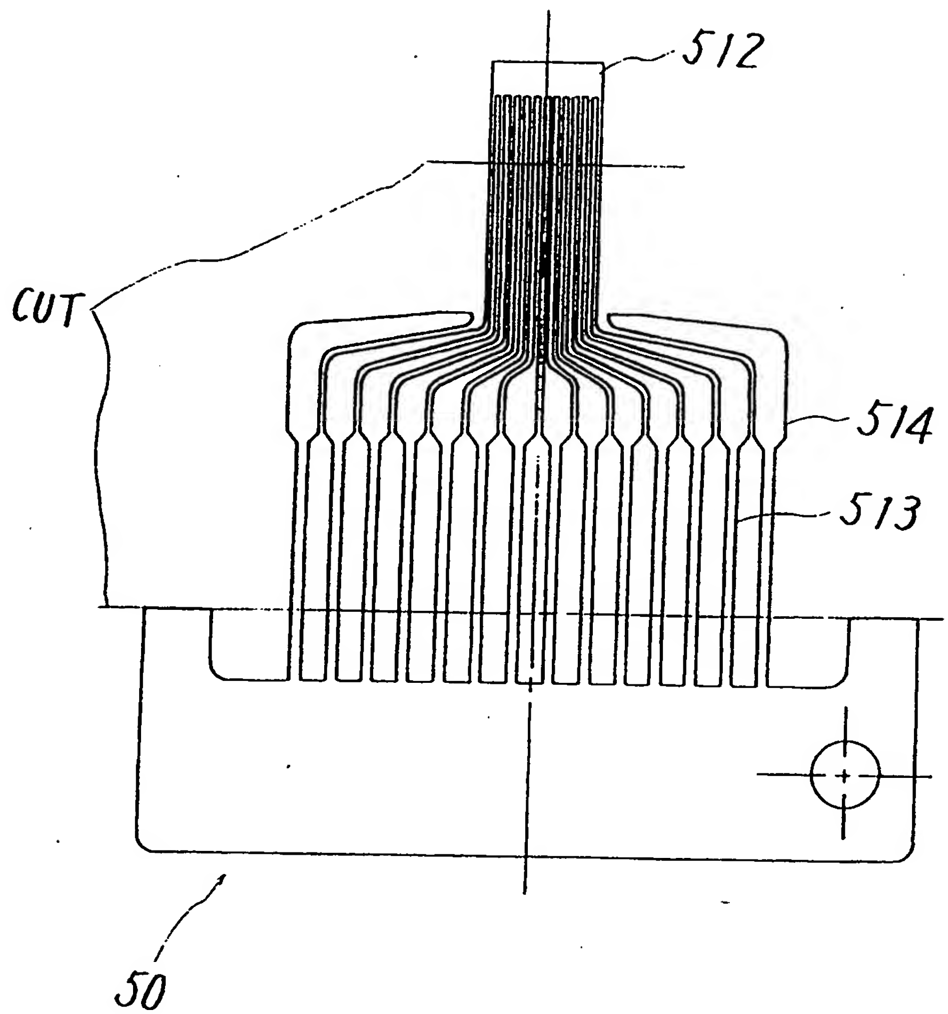


FIG. 41

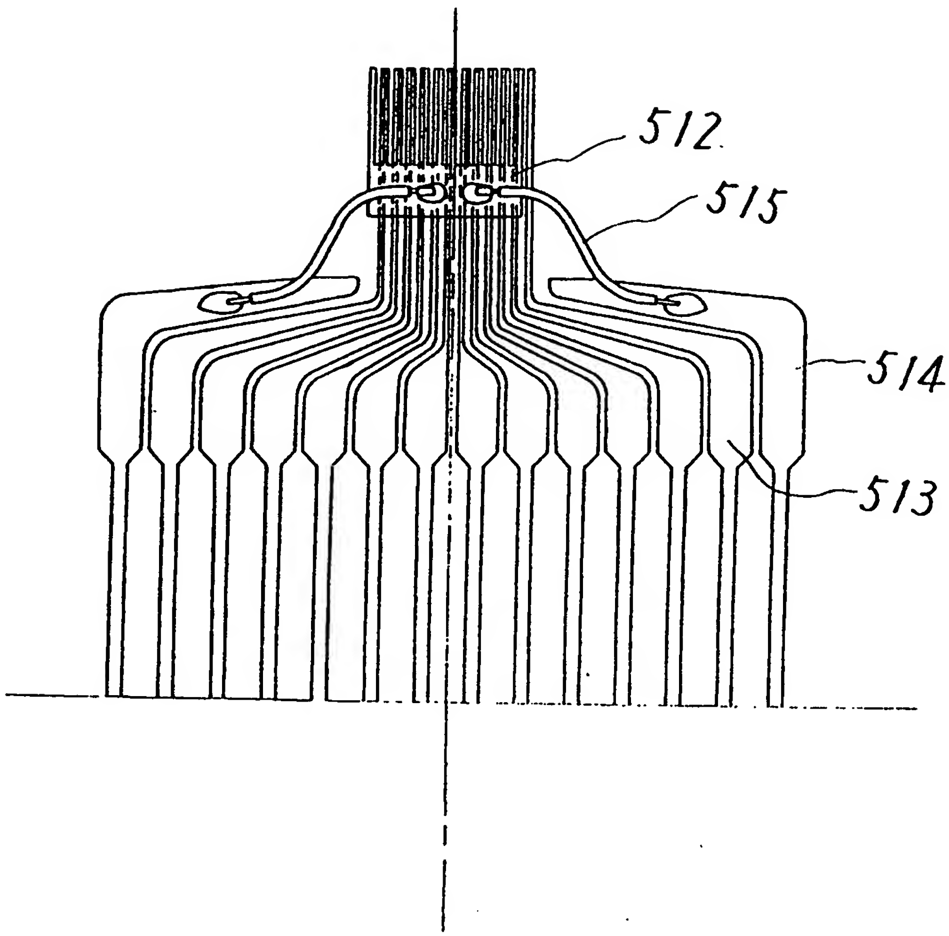


FIG. 42

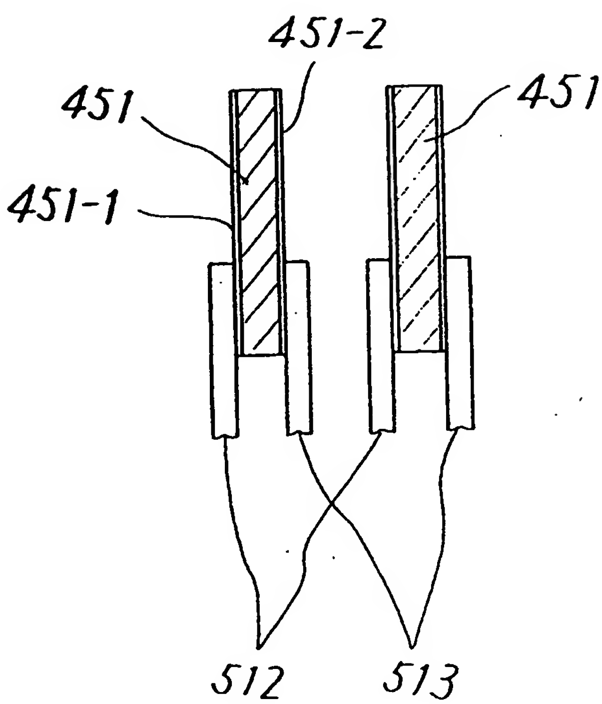


FIG. 43A

PRIOR ART

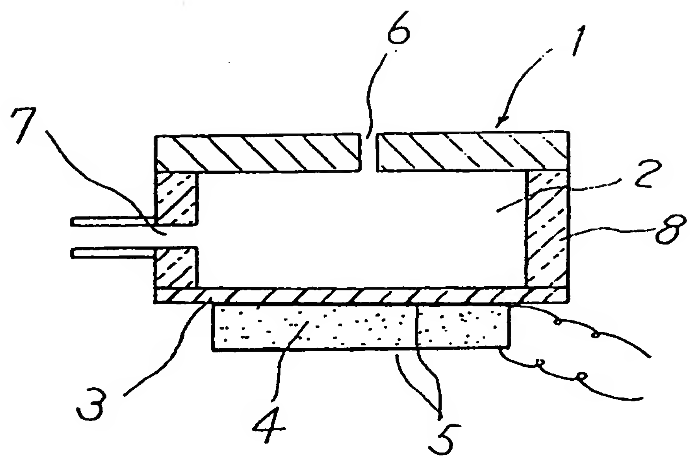


FIG. 43B

PRIOR ART

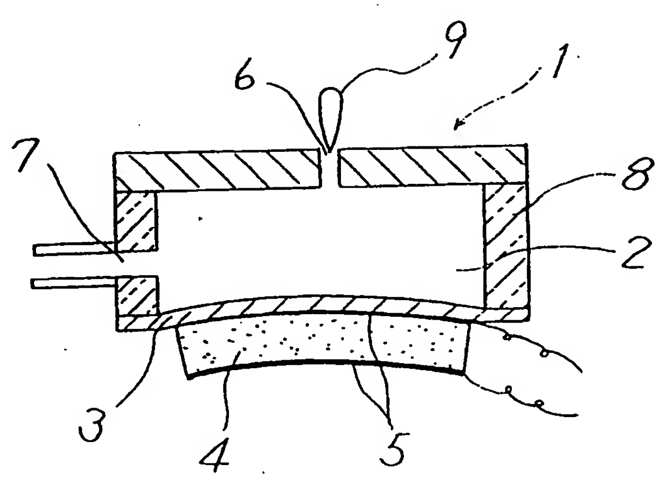


FIG. 44A

PRIOR ART

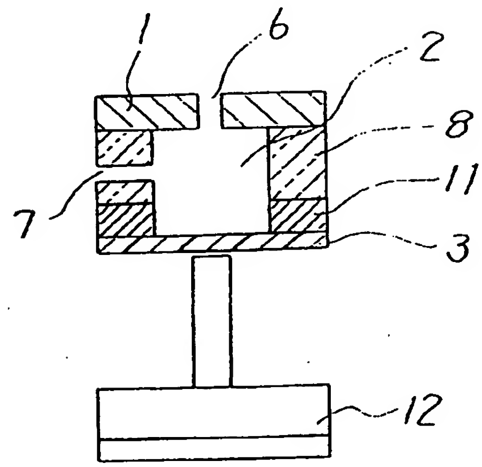


FIG. 44B

PRIOR ART